WASHINGTON OBSERVATIONS FOR 1875.—APPENDIX II.

RESEARCHES

ON THE

MOTION OF THE MOON.

MADE AT THE

UNITED STATES NAVAL OBSERVATORY, WASHINGTON,

BY

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PART I.

REDUCTION AND DISCUSSION OF OBSERVATIONS OF THE MOON BEFORE 1750.

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PREFACE.

For several years after the publication of HANSEN'S Tables of the Moon, it was very generally believed that the theory of the motion of that body, after having been the subject of astronomical and mathematical research for two thousand years, was at last complete, and that, in consequence, the motion of the moon could now be predicted with the same accuracy as that of the other heavenly bodies. In 1870, the writer showed that this belief was entirely unfounded, and that the correctness of the tables since 1750 had been secured only by sacrificing the agreement with observations previous to that epoch, so that, about 1700, HANSEN'S Tables deviated more widely from observations than did those which they superseded. It was also shown that at the time of writing, the moon was falling behind the tabular position at a rate which would speedily cause a very serious error in the representation of the Tables. Altogether, it appeared that notwithstanding the immense improvement which HANSEN had made in the accuracy of the inequalities of short period, the theory of those of long period was no nearer such a solution as would agree with observation than when it was left by LAPLACE.

The work of reinvestigating the subject, and, if possible, of ascertaining the cause of these deviations, was soon after, with the concurrence of Rear-Admiral SANDS, made a part of the author's official duty at the Naval Observatory. It may be proper to remark that this arrangement was largely due to the interest taken in the subject by Captain (now Rear-Admiral) DANIEL AMMEN, U. S. Navy, the Chief of the Bureau of Navigation.

The work as planned was divisible into two distinct parts:—

1. The mathematical theory of the inequalities of long period in the moon's mean motion. As the only cause to which such inequalities could be attributed was the action of the planets, this part of the investigation resolved itself into a computation of that action.

2. The study of the inequalities in question from observations, especially from observations before 1750. In the ancient and modern observations of eclipses and occultations, there was believed to be an immense mass of valuable material for the purpose in question, some of which had been almost forgotten, and very little of which had been discussed with modern data.

An amount sufficient for the employment of two computers having been appropriated by Congress, these two investigations were carried on simultaneously, with the intention of completing them in the order in which they have been named. But as the mathematical investigation was supposed to be nearly brought to a close, it was found that certain terms, which were at first supposed to be of no importance, would have to be investigated, and that this investigation might prove the most tedious part of the whole work, unless some method of shortening it could be devised. Not having

yet been able to decide which is the best method of treating the subject, the investigation is still incomplete, and the present research, originally intended as Part II, is issued as Part I.

In 1871, advantage was taken of a journey in Europe to ascertain whether the older observatories and libraries of that continent might not contain unpublished observations of eclipses or occultations which would be of value for the subject in hand. In this, an unexpected measure of success was attained. At Paris, M. DELAUNAY, then the Director of the Observatory, placed all the archives of that establishment unreservedly at my disposal. Among this material were most of the original note-books of the French astronomers from 1675 onward, and here a great number of occultations were found to have been observed, though the observations had been totally forgotten. The observations published in the Memoirs of the Academy were but a small fraction of those actually observed, and that fraction was composed of the least valuable of them.

One circumstance connected with these observations, while greatly increasing the labor of the reduction, has also increased the value of the results by insuring the entire genuineness of the records. The records made use of consisted, in large part, of the original rough notes of the observations, without any explanation whatever, and without any reductions except the occasional application of a supposed clock-correction. In perhaps half the cases, the star occulted was neither named nor described, while the methods of determining clock-error had to be ascertained by comparison and induction. Many of the books were entirely anonymous. As the copies of the records of which use has been made are given in full in the present paper, a minute description is not here necessary.

At the observatory of Pulkowa, I was fortunate enough, through the kind offices of Director STRUVE, to find what might be considered as the complement of the Paris observations in the records of DELISLE's observations at St. Petersburg between 1727 and 1747. From about 1720, there was a great falling-off in the number of the Paris observations, so that those of St. Petersburg come in very opportunely. At Pulkowa I also availed myself of the opportunity of making use of the unrivalled astronomical library of the establishment to complete the list of published data. In these researches at Pulkowa I was actively assisted by Dr. LINDEMANN, then acting librarian, who devoted several days to this work.

Another series of observations which, though published, seem to have been nearly forgotten, was found in the *Livre de la Grande Table Hakémite*, translated from an Arabian manuscript by CAUSSIN. These comprise the most valuable of the Arabian observations, but, so far as I am aware, they have not before been fully compared with modern tables.

The want of accurate data in the beginning has added greatly to the labor of completing the present work, and caused much unavoidable delay. In the case of many of the Paris observations, the stars could not be identified until the times of observation had been computed, and the apparent place of the moon at those times found from the tables. Then the star had to be observed, in order to improve the means of determining its proper motion. The existing data for determining the places of stars

two centuries back were so insufficient that a complete reinvestigation of the right ascensions of the stars became a necessary part of the work. This investigation was rendered successful by AUWERS's re-reduction of BRADLEY's observations; and its results have in part been published.

It will be seen that the material most used in the present investigation has hitherto been least known. Possibly, the most valuable portion of it is found in the unpublished Paris observations, whereby the moon's mean longitude is determined with astronomical accuracy from 1680 onward. The observations of GASSENDUS, HEVELIUS, and FLAMSTEED (whereby the mean longitude is carried back with gradually diminishing accuracy a half century farther), though published, have never been used for determining the moon's place. Nearly the same remark will apply to the Arabian observations, though it was by them that the secular acceleration of the moon's mean motion was first determined. On the other hand, the ancient total eclipses of the sun, which have been so much discussed during the present century, are here thrown aside. The reason for this course being given in the proper place need not be repeated now; nor will the writer make any attempt to forestall the differences of opinion which may arise respecting its validity. He will only remark that he approached the subject without any bias whatever, unless a general distrust of the scientific precision of ancient authors may be regarded as a bias, and that the various considerations which presented themselves to his mind on examining these records are here reproduced as exactly as possible. While the result of the examination of ancient solar eclipses has seemed to him to justify his general distrust, that of the lunar eclipses in the *Almagest* has not. Moreover, no part of the discussion has been altered in the light of the result finally reached; but, verbal revision aside, each consideration is given as it was originally written. The only approach to an exception occurs in § 2, from which he has expunged a derogatory estimate of PTOLEMY's eclipses, formed before he had compared them with the tables. The lack of unity and consistency which may thus have arisen in a discussion which has been growing by piecemeal for six years may be excused under these circumstances.

The date 1750 is fixed upon as the terminal point of the investigation, partly because it is that when accurate meridian observations commence, and also because it is the epoch which separates the period within which we have readily accessible observations and copious tables of reduction founded on modern data, from that during which both these requirements are wanting.

In conclusion, the author wishes to place on record his appreciation of the labors of the skilled assistants, without whose help the completion of the work would not have been possible. He owes much to the conscientious accuracy of his young friend, Mr. PARKER PHILLIPS, who, with Mr. JOHN T. HEDRICK, assisted him from 1871 until 1873. In the closing parts of the work, most of the necessary computations were prepared by Mr. JOHN MEIER and Mr. W. F. McK. RITTER. His engagements rendering it difficult to read the proof-sheets properly, Mr. D. P. TODD has taken an active part in passing the work through the press.

NAUTICAL ALMANAC OFFICE,
Washington, April, 1878.

ERRATA.

Page 13, line 5, for Bd. 60 read Bd. 52.
Page 42, Ecl. No. 10, for $5^h\ 56^m$ read $6^h\ 56^m$.
Page 44, line 19, for $+ 18'$ read $- 18'$.
Page 59, line 21, for $L_0 - 111°$ read $L_0 + 111°$.
Page 60, lines 4 and 5, add (7).
Page 74, lines 13 and 15, for π read Π.
Page 84, line 8 from bottom, for $90\frac{1}{2}$ read $99\frac{1}{2}$.
Page 205, line 1, add § 12.
Page 231, line 8 from bottom, for $3.8''$ read $38''$.

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RESEARCHES

ON THE

MOTION OF THE MOON.

PART I.

DISCUSSION OF OBSERVATIONS MADE PREVIOUS TO THE YEAR 1750.

§ 1.

HISTORICAL INTRODUCTION.

In all theories of the moon before the beginning of the last century, the mean motion of that body was supposed to be uniform. The first inequality discovered was the secular acceleration. While the general proposition that a comparison of ancient and modern eclipses shows the mean motion of the moon to have increased since the time of PTOLEMY is no doubt due to HALLEY, I believe the first careful determination of its amount is that by DUNTHORNE.* Going backward, in the order of time, he compares his tables of the moon† with the following eclipses:—

Those of TYCHO BRAHE in his *Progymnasmata;*
Those of WALTHER and REGIOMONTANUS (A. D. 1478–90);
Two of the Cairo eclipses (A. D. 977 and 978);
The eclipse of THEON (A. D. 364);
The eclipses of PTOLEMY.

The first of these series of eclipses was too near his epoch, and the second too unreliable, to predicate anything certain upon. From an examination of the others, he concludes that the observed times will be best satisfied by supposing a secular acceleration of 10″ in a century.

Soon afterward, TOBIAS MAYER deduced an acceleration of 7″ from the eclipses of the *Almagest*, which value he is said to have used in his earlier tables of the moon.

The subject is next discussed by LALANDE in the Memoirs of the French Academy

* *Phil. Trans.*, No. 492, p. 162.

† These tables were probably those published in 1739 (LALANDE, *Bibliographie Astronomique*, p. 410). I know of no copy of them in this country.

of Sciences for the year 1757. Like BULLIALDUS and others of his countrymen, he has grave doubts of the honesty with which PTOLEMY has given the times of his eclipses, and therefore uses only the first of the series, that of −720. He adds the two eclipses observed at Cairo by Ebn JOUNIS, A. D. 977 and 978, and reported in the introduction to the *Historia Coelestis* of TYCHO BRAHE, and thence concludes that the secular acceleration is about 9″.886 per century.

The next event in the history of the problem is the discovery by LAPLACE of the physical cause of the acceleration, and his calculation of its amount, which he fixed at very nearly 10″. The exact agreement of this result, and also that of PLANA, with those derived by DUNTHORNE and LALANDE from observations, seems to have satisfied the next two generations of astronomers that no more exhaustive discussion of the ancient eclipses was necessary. We find an acceleration scarcely differing from 10″ adopted in all the Lunar Tables between those of LALANDE and HANSEN. I am not aware of any investigation having in view a definitive determination of the secular acceleration from observations alone during the century following LALANDE's paper. We have, it is true, two important papers by ZECH in a series of memoirs published at Leipsic under the general title

Preisschriften gekrönt und herausgegeben von der Fürstlich Jablonowskischen Gesellschaft zu Leipzig.

The two papers are:—

III. J. ZECH, *Astronomische Untersuchungen über die Mondfinsternisse des Almagest.* Leipzig, 1851.

IV. J. ZECH, *Astronomische Untersuchungen über die wichtigeren Finsternisse, welche von den Schriftstellern des classischen Alterthums erwähnt werden.* Leipzig, 1853.

The first of these papers has formed the basis of all the late discussions of PTOLEMY's eclipses; but the author finds these eclipses inadequate to give any determination of the moon's secular acceleration, a result which arises from his including the correction of the moon's mean motion, as well as of its secular acceleration, in his equations of condition. If we determine the mean motion, not from the modern observations alone, but from a comparison of the latter with those of PTOLEMY, it is evident that we shall have no accurate data remaining with which to determine the secular acceleration.

In 1853 appeared the celebrated paper of ADAMS, which showed that the theoretical value of the secular acceleration found by his predecessors needed a large diminution. This was followed by several accurate calculations of its amount by ADAMS himself and by DELAUNAY, the latter finally fixing it at 6″.176.* I conceive that no rational doubt can remain that this result represents the true effect of the gravitation of the planets within a small fraction of a second.

In constructing his Lunar Tables, HANSEN introduced the coefficient 12″.18, founded on a theoretical computation. A revision of his calculation, leading to a slightly greater result, namely, 12″.557, is given in his *Darlegung der theoretischen Berechnung der in den Mondtafeln angewandten Störungen* (ii, p. 374). About the time of publication of this work, HANSEN wrote that he had never disputed the correctness of the result of ADAMS and DELAUNAY, and defended his result rather on the ground of its

* *Comptes Rendus*, 1871, i, tome 72, p. 495.

representing ancient observations than on its theoretical correctness.* It can therefore scarcely be cited as tending to invalidate the results reached by these investigators.

It has long been recognized that there was no necessity for an agreement between the values of the acceleration derived from theory and from observation, because a retardation in the earth's motion of rotation would produce an apparent acceleration in the motion of the moon, and the friction of the tides must produce such a retardation. The original discovery of this principle is attributed to MAYER; but it would seem to have been lost sight of for nearly a century, when it was taken up again by FERREL, without any knowledge of MAYER's work. FERREL's first paper was published in 1853 in vol. iii of GOULD's *Astronomical Journal*. It contains the first known attempt to calculate from theory the retardation produced by the action of the moon on the tidal wave. Assuming that the tide caused by the moon in the open sea is two feet in height, and that it is highest two hours after the moon passes the meridian, he finds that, if the ocean covered the earth, the equatorial retardation of the latter would amount to 50 miles in a century. Deducting one fourth for the land surface, he finds the retarding effect of the moon alone to be 37.44 miles in a century, and the combined effects of the sun and moon to be 44.45 miles. If the earth were really retarded by this amount, an apparent secular acceleration of the moon amounting to $.84''$ in a century would be produced. As no such acceleration is observed except what is otherwise accounted for, he concludes that this effect of the sun and moon must be nearly balanced through the gradual contraction of the earth by loss of temperature.

After the researches of ADAMS and DELAUNAY, and the general concession of the correctness of their results, FERREL returned to the subject in a paper on *The Influence of the Tides in causing an Apparent Secular Acceleration of the Moon's Mean Motion*, read before the American Academy, December 13, 1864.† Reversing the process of his former paper, he finds that the unaccounted-for apparent secular acceleration of $6''$ corresponds to a mean retardation of the tidal wave of 8 minutes, or to a retardation of 10 minutes if we suppose the earth to be cooling according to FOURIER's theory.

Two or three years after these papers by FERREL were published, but before they became known in Europe, DELAUNAY read a paper before the French Academy of Sciences on the same subject,—*Sur l'existence d'une cause nouvelle ayant une influence sensible sur la valeur de l'équation séculaire de la lune.*‡ Here the distinguished author demonstrates the retarding influence produced by the attraction of the moon on the tidal wave, following a course of reasoning similar to that of MAYER and of FERREL. It was through this paper that the subject was first brought prominently into notice and discussion.

Since in the action of the moon and the cooling of the earth we have two known causes which produce a secular variation in the mean day, the accurate effect of which cannot be computed deductively, it will probably not be disputed that the real result to be derived from observation is, not the acceleration of the moon's mean motion, but the retardation of the earth's rotation on its axis. Although the phenomenal effects

* *Monthly Notices, R. A. S.*, vol. xxvi, p. 187. There is a short discussion of this subject by HANSEN in vol. xv of *Berichte der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig*, Leipzig, 1863, in which he discusses tidal retardation, and defends his coefficient on the grounds above indicated.

† *Proceedings of the American Academy of Arts and Sciences*, vol. vi, p. 379.

‡ *Comptes Rendus*, tome lxi, p. 1023, December 11, 1865.

of these two causes are nearly identical, they are not absolutely so. The longitudes of the sun and of the lunar perigee and nodes will, in fact, be affected by a secular inequality when expressed in terms of a variable unit of time. The effects of these apparent inequalities are, however, too minute to admit of detection by observation for a long time to come.

From what has been said, it will be seen that the value of the secular acceleration adopted in HANSEN'S Lunar Tables can hardly be considered as having any sufficient *a priori* foundation. It was not determined from observation at all, but from theory; and the theory was so incomplete as to give a result double that which would have been given by a complete one. If, then, the result agrees with observation, it can only be because the effect of the omitted terms chances to be the same as that of the earth's tidal retardation. Whether they are the same is a question to be settled by observations, especially by those of ancient eclipses. The first of the recent discussions of ancient eclipses having this object in view was made by AIRY.

In the *Philosophical Transactions* for the year 1853, he has a paper *On the Eclipses of Agathocles, Thales, and Xerxes.* The feature of this paper of most interest at the present time is the historical discussion of the circumstances of each eclipse, more especially of the localities in which it was observed to be total. The computations are made from DE DAMOISEAU'S Lunar Tables, with the application of the corrections resulting from the Greenwich observations, and are, for the purpose in question, superseded by a subsequent paper. Shortly after the publication of HANSEN'S Lunar Tables, AIRY returned to the subject in a paper *On the Eclipse of Agathocles, the Eclipse at Larissa, and the Eclipse of Thales. With an Appendix on the Eclipse at Stiklastad*, in the *Memoirs of the Royal Astronomical Society*, vol. xxvi. Here he makes use of the places of the moon calculated by HANSEN from his tables, and of places of the sun from HANSEN'S Solar Tables. He considers the following conclusions fairly deducible from his investigation:—

1. The eclipse at Larissa, —556, May 19, is established as a real eclipse at a well-defined point, and may be adopted for critical reference in deciding on the value of lunar tables, as applicable to distant places of the moon.

2. Professor HANSEN'S Tables very well represent the phenomena of the three eclipses of AGATHOCLES, Larissa, and THALES, as far as we can interpret the historical accounts of these eclipses.

3. If any change is permitted in the two elements of secular acceleration of longitude, and change of the argument of latitude, it must be in the nature of increasing the acceleration, and increasing the argument of latitude in the distant ages.

The eclipse at Stiklastad is discussed in the addendum to this memoir. HANSEN'S Tables throw the limit of totality in the case of this eclipse about a hundred miles south of Stiklastad. To make the eclipses of Stiklastad and Larissa central, it is necessary to increase HANSEN'S secular acceleration by $0''.809$, and his argument of latitude by $49'' \times$ number of centuries preceding 1800. HANSEN'S sidereal acceleration being $12''.18$, this correction increases it to $12''.99$. The effect of these corrections is said to be to throw the shadow-tracks of the eclipses of AGATHOCLES andof THALES to the north, and nearer the points over which the historical evidence seems to

indicate that they passed. In the opinion of the author, a strong presumption is thus produced in favor of their reality.

A comparison of PTOLEMY's series of lunar eclipses, as discussed by ZECH, with HANSEN's Tables, has been made by HARTWIG, and published in the *Astronomische Nachrichten*, Bd. 60. A clear tabular summary of his results is printed in the *Monthly Notices of the Royal Astronomical Society*, vol. xxvi, p. 185. The nineteen eclipses indicate a sensible negative correction to the secular acceleration, the mean being $-1''.9$. Only three out of the nineteen give the correction positive; and, if we regard the series as consisting of observations really independent, the probable error of this result cannot be more than $0''.4$, and its reality would therefore be beyond doubt. The result of these eclipses may therefore be regarded, from this point of view, as incompatible with that derived by AIRY from eclipses of the sun; but the steps of the investigation are not given with sufficient fullness to enable us to judge of the reliableness of any conclusions which might be drawn from it.

It will be seen from the foregoing that the only approach to a definitive answer to the question the question what value, &c., what value of the secular acceleration is deducible from observations, is to be found in the papers of Professor AIRY. If we accept the three most ancient eclipses which he has discussed as all undoubtedly total, then scarcely any deviation from HANSEN's value of the secular acceleration seems admissible. But I cannot conceive that the historic evidence bearing on the subject places the phenomena of totality so far beyond doubt that a discussion of other data is unnecessary.

Such a discussion is the more necessary because it has been known, since the time of LAPLACE, that, in addition to the uniform acceleration of which we have spoken, the mean motion of the moon is apparently affected by inequalities of long period, in the satisfactory explanation of which geometers and astronomers have always found difficulty. The first discussion of such an inequality is, I believe, that of LAPLACE, in *Mécanique Céleste*, 2^e partie, livre vii, chap. v, under the title *Sur une inégalité à longue période, qui paroît exister dans le mouvement de la lune.* The discussion is mainly empirical, the existence and magnitude of the inequality being inferred from observations which showed that the mean motion of the moon during the second half of the eighteenth century was greater than during the first half. It was then assumed that the inequality was a periodic one, due to the fact that twice the motion of the moon's node, plus that of its perigee, is a very small quantity. The value of the coefficient concluded from the observations was $47''.51$, and the expression for the resulting inequality was

$$47''.51\ (=15''.39)\ \sin\ (2\ \Omega\ ☽ + \pi\ ☽ - 3\ \pi\ \odot).$$

Using HANSEN's notation for the lunar elements, namely, ϖ for the distance of the moon's perigee from its node, and ϖ' for the distance of the sun's perigee from the same node, the inequality would be

$$15''.39\ \sin\ (\varpi - 3\ \varpi') = 15''.39\ \sin\ \{173^\circ\ 26' + (1^\circ\ 57'.4)\ (t - 1800)\}.$$

The following table shows how the observations on which the inequality was predicated were found by LAPLACE to be represented by it:—

Date.	Cor. to LALANDE'S Tables per Obs.	Corrections by the Formula.	Error outstanding.
	$''$	$''$	$''$
1691	− 13.58	− 11.48	+ 2.10
1756	0.00	+ 2.10	+ 2.10
1766	− 9.26	− 9.54	− 0.28
1779	− 28.09	− 32.93	− 4.84
1789	− 54.32	− 55.52	− 1.20
1801	− 87.96	− 85.86	+ 2.10

The tables compared with observation were those in the third edition of LALANDE'S *Traité d'Astronomie.* The complete formula for the correction of their mean longitude, as deduced from the comparisons in the second of the above columns, was

$$-39''.44 - 98''.654\, i + 47''.51 \sin(\varpi - 3\,\varpi');$$

i being the number of centuries after 1750.

It would seem that LAPLACE was by no means satisfied with this explanation of the cause of the inequality, as he afterward favored the hypothesis that it was due to an unequal compression of the southern and northern hemispheres of the earth. He found from theory that such an irregularity in the conformation of the earth would produce an inequality in the moon's mean motion depending on the same argument, except that the equinox would have to be substituted for the sun's perigee, and the function *cos* would have to be substituted for *sin.* But a careful analysis afterward showed him that this cause was inadequate, the inequality in question being insensible on any reasonably admissible supposition of the constitution of the terrestrial spheroid.*

The question was next taken up, from a theoretical standpoint, by POISSON, in his *Mémoire sur le mouvement de la lune autour de la terre*, in the *Mémoires de l'Académie des Sciences,* tome xiii, pp. 209–325. It occurred to this geometer that AIRY'S inequality of long period in the motion of the earth due to the action of Venus must involve a corresponding inequality of long period in the eccentricity of the earth's orbit, and must thus produce a corresponding inequality in the secular acceleration, and thence in the mean longitude of the moon; but the computation of the inequality showed it to amount to only two hundredths of a second. In his account of this memoir, published in the *Connaissance des Temps* for 1836, p. 61, POISSON remarks, "Il est facile de s'assurer que l'action directe des planètes sur la lune, ne saurait non plus donner lieu, dans le mouvement du satellite, à aucune inégalité de longue période." He shows that the coefficient of LAPLACE'S first inequality is absolutely zero, at least so far as the terms of the lowest order are concerned. The hypothesis of an inequality in the length of the sidereal day he also considers entirely inadmissible. He hence concludes that no inequality of long period should be admitted in tables of the moon founded on

*Connaissance des Temps, 1823, p. 239.

theory. As to the existence of such an inequality, he thinks the observations are too uncertain to establish it.

It was reserved for HANSEN to show that an inequality of long period did really result from the theory of gravitation, and that it was due to the direct action of a planet.* He first computed LAPLACE's inequality, and, like POISSON, found that its coefficient was entirely insensible; but on developing certain terms in the action of Venus on the moon, which LAPLACE and POISSON had too hastily supposed to be insensible, he found the following inequality in the moon's mean longitude:—

$$\delta l = 16''.0 \sin(-g - 16g' + 18g'' + 35^\circ\ 20');$$

g, g', and g'' being the mean anomalies of the moon, the earth, and Venus respectively. As this expression still failed to account for the observed inequalities in the moon's mean longitude, he carried the approximation to terms of the fourth order with respect to the disturbing force, and found that the terms of the third and the fourth order increased the coefficient to $27''.4$, while the argument remained unaltered; so that the concluded inequality became

$$27''.4 \sin(-g - 16g' + 18g'' + 35^\circ\ 20').$$

But, with this increase, the observations were hardly so well represented as before. The term depending on the argument of AIRY's equation of long period was then computed, and the coefficient found to be $23''.2$. The term was

$$\delta l = 23''.2 \sin(8g'' - 13g' + 315^\circ\ 30').$$

The addition of this term to the other he considered would reconcile theory and observation. In the course of his paper, HANSEN remarks that he did not employ decimals enough in his computation to be able to pronounce with certainty upon the entire seconds of the coefficients: he therefore proposes to repeat the computation, using one or two more decimals.

The periods of these two inequalities are respectively 273 and 239 years. The difference of the periods is so small that, so far as the representation of existing observations is concerned, the two terms might have been combined into one.

HANSEN concludes his paper with an inquiry whether these two inequalities will satisfy the observations. He has before him the corrections to DE DAMOISEAU's theory given by the Greenwich observations from 1750 to 1830, and he finds that the residuals will be satisfied by applying, along with the above inequalities, the following corrections to the moon's mean longitude for 1800, and to its mean annual motion:—

Correction of epoch for 1800	$-5''.09$
Correction of mean annual motion	$+0''.4096$.

He also makes a similar examination of the residuals in the chapter of the *Mécanique Céleste*, already referred to, and finds that these may be represented by applying to LALANDE's positions of the moon, along with the above inequality, the following corrections:—

Correction to mean longitude for 1764	$-24''.0$
Correction to mean annual motion	$-0''.2377$.

Astronomische Nachrichten No. 597.

HANSEN makes no inquiry as to whether these two sets of corrections correspond to the difference between the moon's mean longitude and mean motion given in the two tables compared, and so lead to the same value of the lunar elements. It would not be difficult to answer this question, since both tables are extant, but the answer would be of little interest, owing to our ignorance of the star-places, equinox, or other data on which LAPLACE's observed longitudes rest. The writer cannot learn that any details of these laborious reductions of the observations of FLAMSTEED, LA HIRE, and others were ever published, and his efforts to find the original manuscript investigations, which were cordially seconded by the late lamented DELAUNAY, then director of the observatory of Paris, were fruitless. It is therefore probable that the whole investigation is lost to science.

This important paper is dated 1847, March 12. The next announcement from HANSEN is seven years later, and appears, as a letter to the Astronomer Royal, in the *Monthly Notices of the Royal Astronomical Society* for November, 1854 (vol. xv, p. 8). He says:—

"The accurate determination of these two inequalities by theory, is the most difficult matter which presents itself in the theory of the moon's motion. I have on two occasions, and by different methods, sought to determine their values, but I have obtained results essentially different from each other. I am now again engaged with their theoretical determination by a method which I have simplified, and hope to bring the operation to a definitive close."

As two methods, that of "successive substitutions" and that of "undetermined coefficients", are described in his original paper of 1847, and the results of each given, it seems probable that these are the two methods referred to. If so, the first method gave 16″.0 for the coefficient of the first inequality and zero for that of the second, while the second gave 27″ for the first and 23″ for the second. We cannot decide whether the proposed computation with more decimals had or had not been executed.

Our next information is obtained from the completed tables of the moon published in 1857. Using mean anomalies, the expressions for these terms employed in the tables are

$$15''.34 \sin(-g - 16g' + 18g'' + 33^\circ 36')$$
$$+ 21''.47 \sin(8g'' - 13g' + 4^\circ 44').$$

The first of these terms is no doubt the result of the revised calculation described as in progress in the letter of 1854. But the second term is partially or wholly empirical, it being found necessary to alter the theoretical value to represent the observations of the moon from 1750 to 1850. What theoretical value HANSEN actually found by his revised computation we do not know. His last and only explication of the matter is given in a letter to the Astronomer Royal dated 1861, February 2, a translation of which is found in the *Monthly Notices of the Royal Astronomical Society* for March, 1861 (vol. xxi, p. 153). He says:—

"For the rest, I have found the coefficient of 8V − 13E, by my last theoretical determination of it, by no means insensible, like DELAUNAY. Without the introduction of this coefficient, the observations show deviations at different epochs; but with the

introduction of this, these deviations disappeared even to the last trace. I consider, therefore, its introduction as established, and reserve to myself a new theoretical determination of it, but cannot take this in hand until I shall have proceeded further in the calculation of the remaining coefficients. I have, besides, some other inequalities of long period, which are caused by the planets; but as the coefficients of these inequalities are small, I have neglected them in the tables, in order to avoid too great extension."

So far as the writer is aware, this is the last utterance of HANSEN on this subject. In his *Darlegung*, published in 1865–66, we find no reference whatever to these terms.

DELAUNAY is the only other geometer who has attacked the problem of these inequalities. His researches are published with great fullness in the Additions to the *Connaissance des Temps* for 1862 and 1863. For the first approximation to the first inequality, his result is

$$16''.02 \sin(-g - 16g' + 18g'' + 35^\circ\ 20'.2),$$

a result almost exactly identical with that first given by HANSEN in 1847. The ulterior approximations lead to the definitive value

$$16''.34 \sin(-g - 16g' + 18g'' + 35^\circ\ 16'.5),$$

a result one second greater than the definitive value adopted by HANSEN in his tables.

In the case of the second inequality, he finds a coefficient of only $0''.27$, a quantity quite insignificant in the present state of the question. We here find an irreconcilable difference on a purely theoretical question, on which no light has been thrown within the last fifteen years.

That the subject of the theoretical computation of the inequalities in the moon's mean motion produced by the action of the planets is by no means exhausted appears from the recent announcement by Mr. NEISON, of England, that he has found an inequality of 16 years, due to the action of Jupiter. As this question involves that of the uniformity of the earth's rotation, it is one of those most worthy of the attention of geometers.

§ 2.

SUMMARY OF THE DATA NOW AT OUR DISPOSAL FOR DETERMINING THE APPARENT SECULAR ACCELERATION OF THE MOON FROM OBSERVATION ALONE.

It has long been tacitly assumed that we are dependent solely on the accounts of eclipses transmitted to us by history for the data necessary to prosecute the investigation in question. This view has undoubtedly been correct in times past. The effect of the cause sought increasing as the square of the time, the extreme roughness of the ancient observations has been more than counterbalanced by their remoteness. For instance, if the mean motion of the moon at the present epoch were accurately known, the secular acceleration could be determined equally well from an observation one century back, and from an observation twenty centuries back affected with an error four hundred times as great. As there must be a long series of modern observations to determine the mean motion itself, any error in which will affect the comparisons by which the secular acceleration is to be determined by an amount

increasing as the simple time, a still farther advantage is thus given to the ancient observations. We may see this advantage in the strongest possible light by reflecting that, with a value of the secular acceleration one second in error, the motion of the moon during a period of two centuries might still be represented without an error of more than half a second.

Notwithstanding these disadvantages, I think the time has arrived when the observations made between the epoch of the invention of the telescope and the year 1750 are entitled at least to consideration as a means of determining the element in question. As a guide toward determining what observations are to be included in this discussion, and how they are to be used, it is proposed to give a brief summary of all the data at our disposal for determining positions of the moon before the year 1750, and to estimate the accuracy with which the secular acceleration can be found from each class or series of determinations, supposing the necessary favorable conditions to be fulfilled. Among these conditions must be included a theory of the inequalities of long period which shall accurately represent observations without any empirical correction, a desideratum which, as we have shown, astronomy does not yet possess. The observations will be divided into classes or series, each class or series presenting some common feature by which the data are to be judged. We begin with

I. *Statements of ancient historians from which it is inferred that the shadow of the moon passed over certain points of the earth's surface during certain total eclipses of the sun.*

If there were even a few cases in which this inference could be drawn without reasonable doubt, this class of observations would doubtless furnish us the most accurate data we possess for our present object. Considering only the eclipses at Larissa and Stiklastad, it appears, from the investigations of Airy just described, that the limits of the value of the secular acceleration within which both eclipses will be total are very narrow, being only a small fraction of a second. But it seems to me that there is in nearly all these descriptions of phenomena too much vagueness to inspire us with entire confidence that any given eclipse was really total at the supposed point of observation. Reserving for the special discussion of each eclipse the difficulties which are peculiar to it, I shall here mention some of a general nature.

The first difficulty is to be reasonably sure that a total eclipse was really the phenomenon observed. Many of the statements supposed to refer to total eclipses are so vague that they may be referred to other less rare phenomena. It must never be forgotten that we are dealing with an age when accurate observations and descriptions of natural phenomena were unknown, and when mankind was subject to be imposed upon by imaginary wonders and prodigies. The circumstance which we should regard as most unequivocally marking a total eclipse is the visibility of the stars during the darkness. But even this can scarcely be regarded as conclusive, because Venus may be seen when there is no eclipse, and may be quite conspicuous in an annular or a considerable partial eclipse. The exaggeration of a single object into a plural is in general very easy.

Another difficulty is to be sure of the locality where the eclipse was total. It is commonly assumed that the description necessarily refers to something seen where the writer flourished, or where he locates his story. It seems to me that this cannot

be safely done unless the statement is made in connection with some battle or military movement, in which case we may presume the phenomena to have been seen by the army.

II. *The series of lunar eclipses recorded by Ptolemy in the Almagest, and used by him as the foundation of his lunar theory.*

These are nineteen in number. They were observed at Babylon, Rhodes, and Alexandria, and extend over a period of eight centuries. Supposing them to be affected only with the accidental errors of observation, the comparisons with HANSEN's Tables made by HARTWIG seem to indicate that the probable error of each recorded time is between fifteen and twenty minutes. The probable error of a mean epoch derived from all the observations will then be about four minutes, and the corresponding probable error of the moon's mean longitude will be $2'$. But there are two circumstances which prevent our assigning quite this degree of accuracy to PTOLEMY's record.

The first is applicable to all observations of the beginning and end of eclipses. It is that the first contact is never really seen, and the eclipse can never become visible until a sensible interval *after* the time of real contact. We must expect that, as a general rule, the recorded times of the beginning of eclipses will be too late by a certain sensible amount, and those of the end too small by an amount somewhat less.* If we knew that the observers had always been on the alert for the eclipse, and keenly alive to the necessity of seeing it at the earliest moment, and of noting its time immediately, some estimate of the intervals in question might be made, and the results corrected accordingly. But, in these observations, we cannot safely apply any such estimate, and must determine the sum of the two errors from the discordances between beginning and end. In the case of eclipses in which only the time of the middle is given, we have no means of knowing whether this time is a mean of observed times of beginning and ending, or whether, in the case of partial eclipses, it was the time when the observer thought the eclipse had reached its greatest phase. Happily, where beginnings and endings are both observed, the errors will be in opposite directions, and will partially eliminate each other. The only remaining doubt will arise from our ignorance of the amount by which the error of the beginning exceeds that of the end: in general, I should think the ratio would lie between 1.5 and 2, a range which reduces the outstanding uncertainty to a quite small amount.

The other circumstance is that the observations which have reached us are not a complete series, but only a selection made for the foundation of a theory—possibly a preconceived theory. In fact, PTOLEMY has been strongly suspected of selecting such observations from the records as would make the results fit his theory. BULLIALDUS founds this accusation upon PTOLEMY's own statement that HIPPARCHUS employed a different interval between two of his eclipses from that calculated by himself. But it does not seem probable that one who had dishonestly altered the records in his possession would have thus frankly stated the result of his alteration. It seems more likely that there was something in the calculation of HIPPARCHUS which PTOLEMY failed to understand, a circumstance not at all improbable.

* Since this was written, an examination of eclipses has led me to suspect that the older observers often anticipated the times of their actually seeing an eclipse become sensible to the sight, and recorded an estimated time of true geometrical contact.

My own judgment of the reliableness of PTOLEMY's lunar eclipses is founded on these considerations. First, they are not to be accepted without question, because the fact that PTOLEMY deduced from a comparison of his own equinoxes with those found by HIPPARCHUS the same erroneous value of the equinoctial year ($365^d\ 5^h\ 55^m\ 12^s$, a quantity too great by $6^m\ 26^s$) which HIPPARCHUS himself deduced, leads to a very strong suspicion that his observations might be in some way made or selected to fit a preconceived theory. Yet all of PTOLEMY's *Almagest* seems to me to breathe an air of perfect sincerity. We must remember that the scientific logic to which a selection of observations is opposed had then no existence in men's minds. The question arises whether we have any strong reason to fear that the observations quoted by PTOLEMY were selected to confirm some preconceived theory of the moon's motion; and, if so, whether such a selection would be likely to result in making the moon's mean longitude systematically incorrect during the eight centuries through which the observations extend. Expressing no opinion on the former question, I am inclined to answer the latter in the negative. Even if there was such a selection, it was probably made in favor of a theory of the moon's mean motion founded on other observations now lost, and therefore entitled of itself to weight. The elements which PTOLEMY sought to determine from the observations in question were so numerous that it does not seem likely that the mean longitude of the moon would be systematically erroneous throughout the whole series. I consider that, on the whole, the observations in question are much more reliable than the accounts of supposed total eclipses, and yet that their confirmation by independent data is very desirable.

III. Passing over, for the present, a number of isolated observations, all deficient in precision, we reach the observations of the Arabian astronomers. We have already remarked that both DUNTHORNE and LALANDE, in determining the secular acceleration, made use of two eclipses observed at Cairo in the tenth century. These seem to have been derived from the *Prolegomena* to the posthumous collection of TYCHO BRAHE's observations, published under the title of *Historia Coelestis*, where they are given on the authority of SCHICKARD. These observations were derived from an Arabic manuscript belonging to the University of Leyden, of which little was known until near the end of the last century. It was then loaned to the French government, and a translation was made by CAUSSIN, and published by the government in 1804, under the title of *Le Livre de la Grande Table Hakémite*. The greater part of the eclipse observations had previously been published in *Mémoires de l'Institut National des Sciences et Arts.—Sciences Mathématiques et Physiques*,—Tome ii, Paris, An vii; but a few changes are made in the separate edition.

I think this work contains what are entitled to be considered the earliest astronomical observations of eclipses which have reached us. Some of the data left us by PTOLEMY, THEON, ALBATEGNIUS, and others may be results of astronomical observations; but in no case, so far as I know, have the quantities actually observed been handed down to us. For example, we can neither regard midnight nor the middle of an eclipse as capable of direct observation; but, in the present work, we find given the altitudes of celestial bodies at the moments of beginning and ending of eclipses,—data which are not likely to be tampered with to agree with the results of calculation. The entire number of eclipses recorded is twenty-eight; of which both beginning and

end were usually observed. The altitudes are given sometimes in whole degrees only, sometimes in coarse fractions of a degree. If they were always given to the really nearest entire degree, so as to be affected with a probable error of only fifteen minutes, the corresponding error in the moon's mean longitude would average about forty or fifty seconds of arc, and would therefore be very small in the mean of all the observations. The most serious source of error is that already alluded to,—the uncertainty how long after the first contact the eclipse was first perceived and the altitude taken, and how long before the actual end it was lost sight of. It is not of much use to guess these quantities until we discuss the observations; but I hope that the probable error of the mean of all the observed times can be reduced to less than two minutes, so that the probable error of the moon's mean longitude will be not more than a minute of arc.

IV. *Observations by Europeans before the invention of the telescope.*

Regiomontanus and Walther.—So far as I can learn, we have nothing that can properly be termed astronomical observations of eclipses between those of the Arabians and those of REGIOMONTANUS and WALTHER in the latter part of the fifteenth century. My authority for them is a volume containing two works, paged separately, under the respective titles:—

(1) *Coeli et Siderum in eo errantium observationes Hassiacae illustrissimi principis Wilhelmi Hassiae, landgravii auspiciis quondam institutae et spicilegium biennale, . . . quibus accesserunt Joannis Regiomontani et Bernardi Waltheri observationes Noribergicae. Lugduni Batavorum,* 1618.

(2) *Johannes de Monte-Regio, Georgii Puerbachii, Bernardi Waltheri ac aliorum, eclipsium, cometarum, planetarum ac fixarum observationes. . . .*

These observations belong to the same class with those of the Arabians, namely, altitudes of the sun or moon at the times of the beginning or ending of the eclipses, and do not seem in any way more trustworthy. The telescope not being known, the same uncertainty must rest over the question of the exact phase at which the eclipse became visible or disappeared from view. The altitudes are given only in coarse fractions of a degree. The epoch being less than half as remote as that of the Arabian observations, the coefficient of secular acceleration will not be one fifth as great. For this reason I do not consider these observations worth using at all.

Tycho Brahe.—The observations of TYCHO follow those of REGIOMONTANUS by about a century. The confused manner in which most of the works of this astronomer have been edited and published makes exact researches into their subjects rather difficult, and it is the less necessary to present any such researches that I have decided to make no use of the observations. I have been led to this course by the following considerations. The telescope was unknown to TYCHO. Granting that the most careful observations were made by him, the probable constant error of contacts observed without a telescope, and, without any means of determining the smallest amount of impingement of the moon on the sun or of the earth's shadow on the moon which he could see, can hardly be estimated at much less than 20″. A number of accurately determined times of contact would be necessary even to reduce the error to this amount. After devoting considerable time and labor to an examination of what pur-

port to be the observations of TYCHO, both those printed, and those in manuscript at the Paris Observatory, I was scarcely able to find what could be regarded as accurate and reliable observations of eclipses. In the *Progymnasmata*, there is a series of some thirty solar and lunar eclipses observed by him between 1572 and 1600. Only a single time is given for each eclipse, and from a comparison with the *Historia Coelestis* it may be conjectured that these are the times of greatest phase. Comparing the dates in this series with the observations, which are arranged in chronological order, only some of the later eclipses were to be found at all. Among these few I found scarcely an unequivocal observation of the beginning of an eclipse, and only occasional observations of an ending. The phases were given, not by measure, but by drawing a diagram showing how the eclipse appeared from time to time. There was no evidence that these diagrams had been laid down by measure, either by the astronomer or by the copyists who followed him. It was generally doubtful whether the times were apparent times, or those of one or the other of two clocks. Finally, the discrepancies between the manuscript and the observations printed in the *Historia Coelestis* were so numerous as to destroy all confidence in either.

It is wonderful if so indefatigable an observer never observed an occultation of a star or planet by the moon, yet I have never succeeded in finding any such. I made a careful examination of his observations during the periods in which occultations of Aldebaran must have occurred without finding any allusion to such a phenomenon.

V. *Observations made with the telescope, but without a clock.*

Bullialdus and Gassendus.—The application of the telescope to the observation of eclipses and occultations may be considered as commencing with these observers. They had no clock. The times were fixed by noting the altitude of the sun or some bright star at the moment of the phenomenon. GASSENDUS sometimes had an assistant, who used the quadrant, while he himself noted the time of the phenomenon by a signal.

This mode of observing ought to be susceptible of considerable accuracy. GASSENDUS's quadrant seems to have read at least to 5′, and an altitude of the star to the nearest 5′ would generally be equivalent to a place of the moon to the nearest 15″. In other words, the probable error in the moon's position would be only about 4″, if the altitude were really noted to the nearest 5′. But the observations of GASSENDUS exhibit anomalies which I find it difficult to account for. He frequently gives the altitudes of two or more objects corresponding to the same occultation, though it is quite certain that only one could have been observed at the proper moment. In these cases, we should expect the second altitude to give a time systematically a little later. Sometimes we actually find it so, but sometimes it is earlier. When the same pair of stars are thus repeatedly observed in the course of a series of occultations observed on a single evening, we generally find the difference of the computed times nearly the same; but, another pair being observed at another time, the difference changes its character entirely. The most embarrassing case is that of the occultation of γ Capricorni, 1635, August 26, where he gives in succession the altitudes of α Arietis, the moon's limb, and α Andromedæ, and adopts a time near the mean of the three results, of which the extremes differ more than three minutes.

I have found no other case so bad as this. The general agreement of the obser-

vations is such that we may generally consider each time to be affected with a probable error not differing greatly from fifty seconds, corresponding to a change of 25″ in the longitude of the moon. We have no means whatever of judging whether the observations of BULLIALDUS are better or worse than those of GASSENDUS, and so may for the present assume them to have the same value. We have, in the observations of both, the equivalent of about twenty observations to dispose of; and, if each gives the moon's longitude with a probable error of 15″, the mean of all may be assumed to be good within 5″ or 6″. The mean epoch will not be far from 1640.

VI. *Observations of Hevelius.*

The observations of HEVELIUS, as given in his *Machina Coelestis* and *Annus Climactericus*, extend from 1639 to 1683. With them commences the use of the clock in the observations of eclipses and occultations, the clock being regulated by observed altitudes of the sun or stars. This gives us more definite means of estimating the probable errors of the observed times, which may be inferred from the discordance of the separate determinations of clock-error. From the best estimate we can form, the probable error of the several determinations of time will fall between 20 and 24 seconds. Taking the latter limit, the probable error of each determination of the moon's longitude will be about 12″. We have in the work of HEVELIUS the apparent equivalent of about forty average occultations to dispose of. The probable error of the moon's longitude which results from the mean of all his observations will therefore, if no other errors than such accidental ones as these enter, not be more than 2″. Allowing for probable unknown causes, we may estimate it at 3″. The mean epoch is about 1675.

VII. *Observations approaching the modern requirements in respect to precision.*

Flamsteed.—Flamsteed's observations were made on the same system as those of HEVELIUS, but with far greater accuracy. His quadrant was supplied with "telescopic sights", which HEVELIUS never adopted, and by which the probable error of the time deduced from a single altitude was reduced to two or three seconds. His clocks were much better than those of HEVELIUS, though far inferior to those of his contemporaries on the continent. A partial drawback to these advantages is that his clock-error was not determined often enough, nor near enough to the times of observations. Another weak point, which is also a mark of HEVELIUS's observations, is that he never seems to have had the idea of eliminating any possible index-error of his quadrant by altitudes on opposite sides of the meridian, but would, month after month, if not year after year, determine nearly all his clock-errors by observations in the east alone, or the west alone. An estimate of their probable error would therefore be such mere guesswork that I shall not attempt it.

The Paris astronomers.—With the foundation of the Paris Observatory, a yet farther improvement was made in the art of determining the time, and one so great that the observations of occultations made there between 1680 and 1720 are frequently comparable in accuracy with those of the present time. The mode of determining the clock-correction was substantially as follows:—A quadrant, gnomon, or meridian-mark was set as nearly as practicable in the plane of the meridian, and was left undisturbed in position during long intervals. With this instrument, the clock-time of meridian

transit of each limb of the sun was assiduously observed on every day that the weather permitted. The clock-time of meridian passage was also determined from time to time by equal altitudes of the sun on the two sides of the meridian, observed with a quadrant. The time deduced from the equal altitudes being compared with that deduced from the meridian passage gives a correction to the meridian-instrument applicable to the particular altitude of the sun on that day. The correction being found for various altitudes of the sun, its value for any particular altitude may be found by a curve or by interpolation, and thus the correction for each day may be deduced.

From the general accordance of the different results for clock-error and for the correction of the meridian, as well as from the discordance of independent observations of the same occultation, it may be inferred that the probable error of a time well determined in this way was not more than two seconds, corresponding to an error of $1''$ in the moon's longitude. This is so small that it does not exceed the probable error arising from the irregularities of the moon's limb, which, from a comparison of occultations observed at various places, would seem to be nearly $1''$. The probable error of the position of the moon's centre will therefore vary from $1''$ to $1''.4$, according to the point of the limb on which the occultation was observed. The probable error of the star places and of the tabular perturbations is larger than this, and may be expected to increase the probable error to $3''$. After gleaning out all the uncertain observations, we shall have the equivalent of more than sixty good occultations observed at the Paris Observatory between the years 1680 and 1720. These ought to give the mean longitude of the moon for the epoch 1700 without a probable error of more than $0''.6$.

Of the same class of observations here described are those made by DELISLE at St. Petersburg between the years 1724 and 1748. In fact, during the interval 1720 to 1753, we have an average of nearly one good occultation per year at St. Petersburg and Paris, so that the mean longitude of the moon can be fixed during this interval within one or two seconds of arc.

VIII. *Observations since the time of Bradley.*

From the year 1750 to the present time, we have a nearly continuous series of occultations and eclipses, observed with a high degree of accuracy at observatories whose positions are well known, notably those of Greenwich and Paris. Of course, these observations become more and more numerous as we approach the present time. Let us next inquire how accurately the mean motion of the moon can be determined from these observations. I conceive that between the epochs 1780 and 1820 we shall find at least 150 well-observed occultations. If we omit a third of these as being cases where the star was too far from the line of motion of the moon's center to give a good determination of the moon's longitude, we shall have 100 left suitable for this determination. If we take the probable error of each longitude derived from a single occultation as $2''.0$, which I think is not far from the truth, the probable error of the mean of all will be $0''.20$, and the epoch will be about 1800. Allowing for systematic differences between observers, it may be increased to $0''.30$. Again, from the more numerous observations on both sides of the epoch 1875, we may hope to obtain the moon's mean longitude for that epoch with the same precision. By a comparison of

the two, the moon's mean motion during the first seventy years of the present century will be obtained, with a probable error of $0''.4$, the corresponding epoch being 1837. The two epochs compared, conjoined with the observations between 1820 and 1850, will give the mean longitude for 1837 with a probable error which, for our present purposes, may be regarded as insignificant.

Now, suppose that, with the mean longitude and mean motion thus determined, we carry back the position of the moon to the epochs of the observations previous to 1720, and, considering the difference as due solely to the secular acceleration, determine the latter from the comparison of the observed and computed longitudes, what will be the probable errors of the several results? The probable error of the computed mean longitude will be, with sufficient approximation, $0''.6\ T$; T being the number of centuries from 1837. If we represent by e the probable error of the mean longitude derived from observation, the probable error of the comparison will be

$$\sqrt{0''.36\ T^2 + e^2},$$

and the probable error of the value of the secular acceleration deduced from the comparison will be

$$\frac{\sqrt{0''.36\ T^2 + e^2}}{T^2} = \varepsilon.$$

The values of the several quantities which we have estimated for each series of observations or other data are given in the following table, the last series of numbers being the probable error of the secular acceleration which would result from a comparison of the observations with a lunar theory derived from observations between 1780 and 1875.

Data or observers.	T.	e.	ε.
		$''$	$''$
PTOLEMY'S eclipses	21.4	200.	0.4
Arabian eclipses	8.8	60.	0.8
BULLIALDUS and GASSENDUS	1.95	5.	1.3
HEVELIUS	1.6	3.	1.0
Paris and Greenwich astronomers	1.35	0.6	0.6

From this reasoning, we may draw the following conclusion:—*Granting the fundamental premises on which we have reasoned, the secular acceleration of the moon can be determined with nearly the same order of accuracy from the modern as from the ancient observations.*

The writer is quite conscious that the degree of accuracy here assigned to the results is something to be hoped for rather than expected, and that many astronomers may consider, not without some reason, that the degree of precision attainable has been greatly exaggerated. To judge of the precise state of the question, it may not be amiss to present some considerations on the premises, expressed or implied, from which we have reasoned. They are substantially:—

(1) That a theory can be constructed which shall accurately represent the real and apparent inequalities of long period in the moon's mean longitude. This involves

the three conditions that the motion of the moon is affected only by the gravitation of the known bodies of the solar system; that the effect of this gravitation can be accurately calculated; and that the motion of rotation of the crust of the earth upon its axis is invariable, a uniform secular retardation excepted. A failure in any one of these conditions will destroy the basis of the preceding calculation, and will increase the probable error of the results derivable from the modern observations much more than in the case of the ancient ones. It is useless to speculate upon the probability that these conditions will be fulfilled.

(2) The other hypothesis is that the observations are not affected by any systematic error nearly as great as the probable error of the mean derived from each series of observations. Among the sources of such systematic errors are to be included erroneous longitudes of observatories, constant instrumental errors in the determination of time, and any habit peculiar to the observer by which he systematically observes an occultation differently from the transit of the sun's limb or of a star.

I do not think that these errors will very largely increase the probable error of the results, because occultations, if actually observed, are peculiarly free from systematic error. If we take the probable errors which we have supposed for the moon's longitude at the three epochs 1700, 1800, and 1870, and reduce them to time, they will amount to about $1^s.2$, $0^s.6$, and $0^s.6$ respectively, quantities far greater than the average observed personal equations between different observers. Now, we have tacitly supposed it an even chance that the mean of a series of observations extending over a period of forty years, made by a number of different observers and in a number of different ways, did not exceed 1^s during the interval 1680–1720, and $0^s.5$ during the interval 1780–1820, and I do not think this estimate will seem extravagant. In regard to the possible erroneous difference of longitude between Paris and Greenwich, it is to be remarked that observations were made at both these places during the intervals we have been considering, and in such numbers that the error will be nearly eliminated from the lunar elements.

However, a certain and perhaps very sensible increase in the probable errors of the results is no doubt to be looked for; but a partial or entire set-off against them is to be found in the fact that more observations are actually available than we have supposed to be included in forming the basis of our theory, and, when these are added, the precision of the result will be sensibly increased.

In the preceding enumeration, I have included only classes or series of observations. In addition to these, there is a great number of isolated observations, both ancient and modern, of every variety of excellence, which I have not deemed it necessary to enumerate, because their value can be determined only by comparison and discussion. They will, of course, add slightly to the accuracy of the data for the final determination of the required element. Altogether, I think there would be room to hope that we might obtain the secular acceleration from the modern observations alone, with a probable error of scarcely more than half a second, if only the long-period inequalities in the moon's motion were conclusively settled. This is something which is still in the future.

§ 3.

DISCUSSION OF THE NARRATIVES OF ANCIENT HISTORIANS FROM WHICH IT HAS BEEN INFERRED THAT THE SHADOW OF THE MOON PASSED OVER CERTAIN POINTS OF THE EARTH'S SURFACE DURING CERTAIN TOTAL ECLIPSES OF THE SUN.

The general difficulties in the way of obtaining any approach to certainty respecting the totality of these eclipses have been discussed in the preceding section. We now pass to the special circumstances of each eclipse. The following is, so far as I am aware, a complete list of the eclipses in question which the accounts of the narrators have been supposed to justify us in considering total. They are arranged in chronological order, and are selected without respect to their confirmation by the tables.

1. The eclipse of THALES, —584, May 28, of which the original narrative is in HERODOTUS, i, 74. The eclipse is also mentioned by PLINY, *Hist. Nat.*, ii, 12, and by CICERO, *De Divinatione*, i, 49. This eclipse has, perhaps, been the subject of more discussion during the present century than any other of those under consideration.

2. The eclipse of Larissa, —556, May 19, discussed by AIRY in the *Memoirs of the Royal Astronomical Society*, vol. xxvi, and by HANSEN in his *Darlegung*, ii, p. 376. The original narrative is found in the *Anabasis* of XENOPHON, iii, 4.

3. The eclipse of XERXES, about —479, described by HERODOTUS, *Hist.*, vii, 37. This eclipse has never been identified astronomically. Reference may be made to AIRY's paper in the *Philosophical Transactions*, and to ZECH's prize memoir, already quoted.

4. An eclipse at Athens, —430, August 3, mentioned by THUCYDIDES, *Hist.*, ii, 28. This eclipse is No. 2 of ZECH's list.

5. The eclipse of ENNIUS, —399, June 21, quoted from ENNIUS by CICERO, *De Republica*, i, 16, discussed by HANSEN, *Darlegung*, ii, p. 386.

6. The eclipse of AGATHOCLES, —309, August 14, described by DIODORUS, *Bibl. Hist.*, xx, 5, and by JUSTINUS, *Hist. Philip.*, xxii, 6. This is No. 9 of ZECH's list, and is very fully discussed by AIRY in the *Philosophical Transactions* for 1853, and in his second paper (*Mem. R. A. S.*, xxvi), as also by HANSEN in his *Darlegung*, ii, p. 382.

7. Eclipse of 334, July 17, No. 15 of ZECH's list, which might have been total in Sicily from the description of FERMICUS, *Mat. Ast.*, i, 2.

8. Eclipse of 364, June 16, described by AMMIANUS MARCELLINUS, *Rer. Gest.*, xx, 3, as total at Eoos.

The author not being himself versed in the Greek language, the original narratives of these several eclipses were submitted to Professor HUNTINGTON of the Columbian University, who kindly furnished translations and critical renderings of the several passages which have been used in the discussion. In general, it has not been deemed necessary to quote the original; but wherever this seemed requisite to form a judgment of the subject-matter, it has been done.

1.—THE ECLIPSE OF THALES.

(—584, May 28.)

The account by HERODOTUS is as follows. Professor HUNTINGTON'S translation is annexed:—

HD., i (KA.), 74.

Μετὰ δὲ ταῦτα (οὐ γὰρ δὴ ὁ Ἀλυάττης ἐξεδίδου τοὺς Σκύθας ἐξαιτέοντι Κυαξάρεϊ) πόλεμος τοῖσι Λυδοῖσι καὶ τοῖσι Μήδοισι ἐγεγόνεε ἐπ᾽ ἔτεα πέντε· ἐν τοῖσι πολλάκις μὲν οἱ Μῆδοι τοὺς Λυδοὺς ἐνίκησαν, πολλάκις δὲ οἱ Λυδοὶ τοὺς Μήδους· ἐν δὲ, καὶ νυκτομαχίην τινὰ ἐποιήσαντο. διαφέρουσι δέ σφι ἐπὶ ἴσης τὸν πόλεμον, τῷ ἕκτῳ ἔτεϊ συμβολῆς γενομένης, συνήνεικε ὥστε τῆς μάχης συνεστεώσης τὴν ἡμέρην ἐξαπίνης νύκτα γενέσθαι. τὴν δὲ μεταλλαγὴν ταύτην τῆς ἡμέρης Θαλῆς ὁ Μιλήσιος τοῖσι Ἴωσι προηγόρευσε ἔσεσθαι, οὖρον προθέμενος ἐνιαυτὸν τοῦτον, ἐν ᾧ δὴ καὶ ἐγένετο ἡ μεταβολή. οἱ δὲ Λυδοί τε καὶ οἱ Μῆδοι ἐπεί τε εἶδον νύκτα ἀντὶ ἡμέρης γινομένην, τῆς μάχης τε ἐπαύσαντο, καὶ μᾶλλόν τι ἔσπευσαν καὶ ἀμφότεροι εἰρήνην ἑωυτοῖσι γενέσθαι.

"Now after this (for ALYATTES did not by any means surrender the Scythians at the demand of CYAXARES) there was war between the Lydians and the Medes for the space of five years, in which [period] the Medes often conquered the Lydians, and the Lydians, in turn, the Medes. And, in this time, they also had a night engagement; for as they were protracting the war with equal success on each side, in a battle that occurred in the sixth year, it happened, as the armies engaged, that the day was suddenly turned into night. Now this change of day [into night] THALES, the Milesian, had predicted to the Ionians, placing as the limit of the period [within which it would take place] this very year in which it did actually occur. Now, both the Lydians and the Medes, when they saw night coming on, instead of day, ceased from battle, and both parties were more eager to make peace with each other."

Among the ancient solar eclipses, this is the one which has been the most celebrated, and has given rise to most discussion in recent times. Yet the proof of its reality seems to me by no means convincing. It is true that we may consider the three following propositions to be individually sufficiently well established:—

(1) That a battle between the Lydians and the Medes was ended by an apparently sudden advent of darkness, substantially as described by HERODOTUS;

(2) That on May 28, 584 B. C., the shadow of the moon passed over Asia Minor, as computed from the tables;

(3) That THALES predicted eclipses.

But that these propositions all refer to one and the same event I see no sufficient reason for holding. Their connection may well be real; but its reality is not so well established that I should be willing to predicate anything respecting the changes of the lunar elements upon it. It seems to me that commentators on this eclipse have not sufficiently distinguished between the phenomenon as seen by the contending armies, and the conclusions drawn by the Ionians that that phenomenon was what their favorite philosopher had predicted.

The simple event, as described by HERODOTUS, and as we may suppose it to have been described by the eye-witnesses, would hardly even suggest an eclipse of the sun, or anything else more extraordinary than the regular advent of night, except for the single word *ἐξαπίνης* (suddenly). But, in the ardor of battle, the combatants are apt to be nearly oblivious of the lapse of time, and the gradually increasing darkness of evening might well be unnoticed for some time, so that, when it at last interfered

with the progress of the battle, it would seem to have come on more rapidly than usual. The formation of a very dark heavy cloud about sunset, or shortly after, such a one as is seen fifty times to one occurrence of a total eclipse of the sun in any given place, might render the description literally true. If it be urged that the making of peace indicated something extraordinary or impressive, we may rejoin that there is nothing in the account to indicate it; that if the phenomenon was really that of a total eclipse, the night must have turned back to day again almost before the fighting could stop, a fact which the historian does not mention; and, finally, that the term *νυκτομαχίην* would hardly apply to the case of a battle stopped by a total eclipse in which the darkness lasted only a few minutes and the battle ceased as soon as darkness commenced.

This view of the naked narrative will not, I conceive, be disputed. The evidence in favor of an eclipse rests entirely on the construction put upon the account by the Ionians, or some other parties to whose ears the narrative came. It cannot be supposed that the combatants knew anything about THALES or his eclipse, so they cannot be the authority for supposing that the darkness was that predicted by THALES. Our belief in the eclipse therefore rests on our faith that the Ionians heard a different story of the battle from that given by HERODOTUS, and that they put a correct interpretation on the circumstances. In trying to form a judgment whether they did so, we must take into account what we know must have been the nature of the prediction, as well as the narrative of the phenomenon; because it is on the agreement of the two that all the evidence in favor of the reality of the eclipse rests. Now, keeping within the limits of historic probability, THALES could not have had any other data for prediction than a knowledge of the Saros, which gave the order in which eclipses would occur, and, at the most, such knowledge of the motions of the sun and moon as would enable him to judge whether a given conjunction was nearly central, and at what time of day it would occur. He could not possibly have predicted that the eclipse would be total, and that day would be turned into night, and could scarcely have decided whether it would or would not have been visible in Ionia even as a partial one. If he could predict one, he could predict two or three every year, without being able to say with any certainty in what places any of them would be visible. But any such prediction necessarily involves a knowledge of the exact day of occurrence of the eclipse, and thus the only means by which the Ionians could identify the phenomenon would be the coincidence of the day of its occurrence with that of the prediction. Now, it is remarkable that the narrative says emphatically that the year was correctly predicted, but makes no reference to the yet more striking prediction of the day.

Astronomically, we are not directly concerned with the prediction of THALES, but only with the question whether the circumstance described by HERODOTUS was really the total eclipse which we know occurred in Asia Minor or its neighborhood, B. C. 584. The prediction is important only for the reason that its mention by the historian furnishes the only evidence in favor of the phenomenon being really an eclipse. Another very weak point in the evidence is that we have no historic data for deciding who first drew the conclusion that the darkness which stopped the battle was that of the predicted eclipse. It may have been the Ionians, it may have been some writer to

whose knowledge the occurrences came, and it is quite consistent with the character of HERODOTUS to suppose that it may have been himself. Since, as we have seen, the identification could only have properly rested on the coincidence of the day of the prediction with that of the battle, and since the historian mentions only a coincidence of year, if we accept the eclipse we must suppose that the most striking and important circumstance was dropped from the narrative during the interval between the identification and the narration by the historian. If the historian himself drew the conclusion, without any other data than those he gives and those with which we may suppose him to have been acquainted, then the entire evidence falls to the ground.

Let us now consider what we may suppose to have been more or less probable states of the case. THALES is supposed to have been born B. C. 640, and to have traveled into Egypt at an early age, where he learned astronomy from the priests. Returning home, he probably applied this, and whatever other knowledge he may have gained from research and observation, to the prediction of eclipses. He may have predicted many eclipses from B. C. 610 to B. C. 584, and longer, as he is said to have lived to a great age. His success in the case of the solar eclipse B. C. 584 gave him a wide celebrity, as we know from the tables that this eclipse was total at no great distance from his birthplace. That he predicted only a single eclipse is highly improbable; that, in addition, this one should prove to be total within a hundred miles of his birthplace transcends all reasonable probability.

Some time between the dates we have mentioned, a battle was fought somewhere in Asia Minor, probably very far from the home of THALES, in recounting which some of the participants expressed surprise at the suddenness with which it was stopped by darkness. The story may have passed through several mouths before it reached any one who knew about THALES, and may have been somewhat exaggerated in the narration. At length, it reached the ears of the admirers of the philosopher, who, recollecting what he was doing, and knowing that he had predicted an eclipse for that very year, seized upon the story as a confirmation of the prediction.

Who these persons were, and in what part of the century which elapsed before HERODOTUS they lived, we can only conjecture. We can make many hypotheses, on which the probability of the correctness of the conclusion becomes smaller and smaller, until we approach the time of the historian, when it vanishes entirely. Under these circumstances, it seems to me that while the hypothesis of correctness is not an entirely inadmissible one, it rests on too slight a foundation to be employed as a basis for correcting the lunar tables. The rejection is farther justified by the uncertainty where the battle was fought, and the considerable breadth of the shadow, which leaves us a wide range for central line of eclipse. I shall therefore not make any use of the eclipse of THALES.

2.—THE ECLIPSE AT LARISSA.

The account of this eclipse, as translated by Professor AIRY, is as follows:—

"When the Persians obtained the empire [of the east] from the Medes, the king of the Persians besieged this city, but could not in any way take it. But a cloud covered the sun and caused it to disappear completely, till [*i. e.* to such a degree that] the inhabitants withdrew, and thus the city was taken. Close to this city was a pyra-

mid of stone, 1 plethrum in breadth, 2 plethra in height. Thence the Greeks proceeded 6 parasangs, to a great deserted castle by a city called Mespila, formerly inhabited by the Medes. The substructure of its wall was of squared stone, abounding in shells. The king of the Persians besieged it, but could not take it. ZEUS, however, terrified the inhabitants with thunderbolts, and so the city was taken."

Professor AIRY adds, "It cannot be doubted, I think, that the disappearance of the sun at Larissa was caused by a total eclipse."

I confess myself unable to share the confidence of the Astronomer Royal and of HANSEN that we have here a total eclipse of the sun. The narratives of these times contain many accounts of wonderful occurrences, in which we know that a liberal allowance is to be made for the flight of the imagination; and it is not entirely logical to accept unhesitatingly all those statements which we can reconcile with our knowledge, while we reject all others. No doubt, if we knew the day, or even the year, of the event described by the historian, and found it to be identical with that of a total eclipse, we should be justified in accepting the coincidence without question; but as the uncertainty of date increases, the probability of coincidence becomes less and less. If, at an epoch so remote, we have a century to find our eclipse in, we can select any place at random, with a decided preponderance of chances in favor of our finding one or more eclipses which, making allowance for the uncertainty of the tables, may have been total at the point selected. It appears that the Astronomer Royal had a period of forty years to find the eclipse in, and the fact that one was found in this interval may be considered as rendering the hypothesis of an eclipse somewhat probable. Notwithstanding my want of confidence, I conceive the probability of a real eclipse to be greater than in the eclipse of THALES, while we have the great advantages that the point of occurrence is well defined, the shadow narrow, and, if it was an eclipse at all, the circumstance of totality placed beyond serious doubt.

3.—THE ECLIPSE OF XERXES (ZECH, No. 1).

(— 477 to — 480, spring of year.)

This eclipse occurred during the march of XERXES against Greece, in the same year in which the battle of Salamis was fought.

The descriptions are found in HERODOTUS and ARISTIDES.

From HERODOTUS, vii, 37:—

"When the army, having come out of their winterquarters, in the opening of the spring, fully equipped, set out from Sardis, for the purpose of marching to Abydos; and when they had begun their march, the sun, leaving his seat in the heavens, was concealed from view, and night instead of day came on, though the weather was not cloudy, but was exceedingly clear."

From ARISTIDES, *Scholiast.*, ed. FROMMEL, p. 222 (quoted from ZECH, p. 39):—

"As the king was going against Greece, and had come into the region of the Hellespont, there happened an eclipse of the sun in the east; for it portended to him his defeat, that the sun was eclipsed in the region of its rising, since XERXES also was marching from the east."

If any justification for entire want of confidence in the eclipse of THALES, and in

ancient total solar eclipses generally, were required, it is found in the fact that this description cannot be identified with any total eclipse of the sun. Of all descriptions of such eclipses by the Greek historians, this is the one which is, all things considered, most clear and explicit. No known natural occurrence but a total eclipse of the sun could give rise to the circumstances described by HERODOTUS. The place and the season are clearly specified, and the year is one about which I am not aware that chronologists have entertained any serious doubt. The time of day (morning) is obscurely indicated by the account of HERODOTUS, and clearly stated in that of ARISTIDES; yet the astronomical tables seem to show in the most conclusive manner that no total eclipse of the sun could have been visible at Sardis at that time. I am not aware that any one has given any explanation of the occurrence which will reconcile the statement with the tables. Professor AIRY considers the most probable explanation to be that the eclipse was not one of the sun at all, but that of the moon which occurred B. C. 479, on the morning of March 14.* On this theory, the circumstance first to be remarked is that it is clearly incompatible with the narrative. The incompatibility is explained by Sir GEORGE by supposing that HERODOTUS was mistaken in the single circumstance of the eclipse being one of the sun, that historian repeatedly expressing himself "doubtful on matters of detail which occurred during the movements of XERXES on the eastern side of the Aegean sea". While, however, such a mistake as the substitution of the moon for the sun is quite possible, it must be admitted that the words "instead of day it became night" cannot be thus explained. The explanation, therefore, how probable soever it may be, presupposes so much play of the imagination on the part of the historian as to render him unworthy of that amount of confidence in matters of detail which would justify our changing the lunar tables to accord with his statements.

ZECH† proposes yet another explanation, namely, that the eclipse in question was that of —477, February 16, which, according to the tables of DE DAMOISEAU, was annular at Sardis. If this were correct, it would be necessary to change the usually received date of the battle of Salamis by two years. The question is, however, one of purely chronological interest, because, if the eclipse was not total, no conclusion can be drawn from it astronomically. The accounts of the historians do not enable us to decide whether the annulus was formed at Sardis; hence no conclusion respecting the position of the central line can be drawn.

4.—THE ECLIPSE AT ATHENS.

(— 430, August 3.)

The following is the translation of the description by THUCYDIDES, ii, 28:—

"But in the same manner, at the new moon of the month,—as even in that time alone it seems to be possible for the phenomenon to occur,—the sun was eclipsed after midday, and having assumed a crescent form, some of the stars having also appeared, it again became full-orbed."

From the circumstance that stars were visible, there would seem to be a considerable probability that this eclipse was total. This probability is lessened by the fact that THUCYDIDES describes the sun as having assumed only a crescent form, and by the con-

* *Philosophical Transactions*, 1853, p. 199.

† *Loc. cit.*, pp. 40–43.

sideration that it might have been elsewhere than at Athens that the stars were seen. Still, as the sun must have been a crescent before and after totality, I think the probability in favor of the totality of this eclipse is as great as in the case of any other of those under consideration, though not sufficient to justify the introduction of an equation founded on it.

5.—THE ECLIPSE OF ENNIUS.

(– 399, June 21.)

This eclipse is introduced because some stress is laid upon it by HANSEN. The description rests upon the following extract from CICERO, *De Republica*, i, 16:—"ENNIUS scribit anno CCCL fere post Romam conditam Nonis Junis soli luna obstitit et nox." The probability that this eclipse was total at Rome does not seem sufficiently great to render it worthy of farther consideration. The tables show that there was a total eclipse about the time of sunset; but I see no reason in the statement quoted for assuming that totality occurred before sunset, or that there was any total eclipse at all.

6.—THE ECLIPSE OF AGATHOCLES.

(– 309, August 14.)

Of all the ancient solar eclipses, this is the one of which the totality may be considered as best established, and to which, therefore, we should have least hesitation in making the lunar tables conform. Unfortunately, there is a doubt whether AGATHOCLES, in his passage from Syracuse to Carthage, went on the north or the south side of Sicily. The arguments on the two sides are so evenly balanced that the question can be decided by the lunar tables alone. This renders the point where the eclipse was total so uncertain that the eclipse itself is of little use. By a singular fatality, the admissible limits of the position of AGATHOCLES correspond almost exactly to those of the limits of the moon's secular acceleration. The shadow was unusually broad; and between the two extreme hypotheses, (1) that AGATHOCLES was south of Sicily and the centre of the shadow south of his position by its semidiameter, and (2) that he was north of the island and the centre of the shadow yet farther north, all intermediate ones are equally possible. While, therefore, we may be justified in making it a test of the correctness of the lunar elements that the computed shadow should fall between these limits, we cannot determine those elements from it.

7.—ECLIPSE OF – 217, FEBRUARY 11.

I was led to consider this eclipse from a statement respecting it by RICCIOLUS, who says (*Almagestum Novum*, p. 365), "Addit Silius Italicus densas fuisse & immensas tenebras in Calabria & subductam esse diei lucem." But, on referring to the original authority, we find the eclipse to become indefinite. The lines alluded to occur in describing the wonders which preceded the battle of Cannæ (viii, 634), and are:—

> "Quaesivit Calaber, subducta luce repente
> Immensis tenebris, & terram & litora Sipus:
> Obseditque frequens castrorum limina bubo."

I find that in this eclipse the central line was far down in Africa, so that it may be dismissed with but a single reflection. If so great a misapplication of the words of a narrator can be made by an astronomer of the seventeenth century, what are we to expect of the ancient historians, and especially of HERODOTUS?

8.—A. D. 360, AUGUST 27.

This is No. 16 in ZECH's list, and, from the description given by AMMIANUS MARCELLINUS, would appear to have been total in Eoos. But the tables show the eclipse to have been annular, so that we can deduce nothing from it.

MEDIÆVAL ECLIPSES.

Belonging to the same class with those we have cited, but too modern to be decisive of the question of the moon's secular acceleration, are the eclipse of Stiklastad, A. D. 1030, and the total eclipses in which the shadow of the moon passed over Central Europe in the years 1140 and 1143. The last two have been very carefully discussed, and many points at which the eclipse was total determined from the chronicles of the times, by CELORIA of Milan in his two papers* published in *Memorie del R. Istituto Lombardo di Scienze e Lettere*, vol. xiii.

The preceding list includes, so far as the writer is aware, all the ancient solar eclipses which have been considered total at any definite point of the earth's surface. The general conclusion to which we are led is that there is no one of these eclipses which we can feel reasonably confident was total at a definite point. The proportion of the eclipses which we know from the tables must have been annular, or, at least, which were not total at the points to which they are referred, is so great as to destroy any confidence which might have been felt in the others. Still, if one value of the secular acceleration should represent them much better than another, it cannot be denied that this fact might militate a little in favor of that value which best represented them. While this consideration cannot aid us in determining the value of the secular acceleration, it may help us in deciding which of several competing values is the most probable. To enable the reader to judge of the application of this test, I arrange the eclipses in what seems to me the order of probability of totality, *judging from the narrative alone*, adding the place where each was supposed to be total.

(1)	Eclipse of AGATHOCLES,	−309.	Total in or near Sicily.
(2)	Eclipse of XERXES,	−479?	Total at Sardis.
(3)	Eclipse,	−430.	Total at Athens.
(4)	Eclipse,	+360.	Total at Eoos?
(5)	Eclipse of XENOPHON,	−556.	Total at Larissa.
(6)	Eclipse of THALES,	−585.	Total in Asia Minor.
(7)	Eclipse,	+334.	Total in Sicily.

Of these seven eclipses, the second cannot be identified, while the fourth and seventh must have been annular. We have therefore only four left to test the tables. Of these, the eclipse of AGATHOCLES, the only one in which I can regard the fact of totality as well made out, allows a range of several seconds in the secular acceleration The uncertainty of the remaining three, that at Athens in the year −430, and those of Larissa, and of THALES, has already been discussed. Altogether, it does not seem to me that much light will be thrown by these eclipses on the question of the moon's secular acceleration. It seems to me that the most logical course is to obtain the secular acceleration of the moon from other data, and then to undertake the discussion of the historical evidence anew.

* (1) *Sull'Eclissi Solare Totale del* 3 *Giugno* 1239.
(2) *Sugli Eclissi Solari Totali del* 3 *Giugno* 1239 *e del* 6 *Ottobre* 1241.

§ 4.

THE PTOLEMAIC ECLIPSES OF THE MOON RECORDED IN THE ALMAGEST.

The most complete discussion of these eclipses is that of ZECH, already quoted, in which, however, the treatment is such as not to lead to any definitive result. ZECH's comparisons were made with the tables of DE DAMOISEAU, HANSEN's tables being still unfinished when his paper was prepared. My general plan of proceeding is this:—From the data given by PTOLEMY, and from his interpretation of the data, I form what seems to me the best judgment of the time at which any given phase was actually seen by the observers, and of the probable error of this time, taking care to do this without any knowledge of the way in which the tabular results will come out. For an epoch near this time, the positions of the sun and moon are computed from HANSEN's tables, and thence the times of the geometrical phases of the eclipse. This time is then compared with that observed, and an equation of condition thence deduced. In the equations, the only indeterminate quantities which it is worth while to include are the moon's longitude and the error of the estimate of the phases of beginning and ending, arising from the fact that the eclipse must have advanced past the phase of beginning before being seen, and must have disappeared before the actual ending

In computing the places of the moon, I have not deemed it necessary to take into account the small terms which are included in the tables of double entry, as their probable sum is far below the probable error of the individual observations. The sum of the constants added to these tables, or 0.0022240 in units of the fundamental argument, has, however, been included with the terms, to avoid any constant error arising from this source.

The positions of the places of observation—Babylon, Rhodes, and Alexandria—have been taken from ZECH, as follows:—

Babylon, $2^h\ 56^m$ east from Greenwich; latitude, $+32°\ 15'$.
Rhodes, $1^h\ 53^m$ east from Greenwich; latitude, $+36°\ 27'$.
Alexandria, $2^h\ 00^m$ east from Greenwich; latitude, $+31°\ 12'$.

PTOLEMY's descriptions of the several eclipses are as follows:—

(1)

Ὧν τοίνυν εἰλήφαμεν παλαιῶν τριῶν ἐκλείψεων ἐκ τῶν ἐν Βαβυλῶνι τετηρημένων, ἡ μὲν πρώτη ἀναγέγραπται γεγονυῖα τῷ πρώτῳ ἔτει Μαρδοκεμπάδου, κατ' Αἰγυπτίους Θὼθ κθ̅ εἰς τὴν λ̅. Ἤρξατο δέ, φησιν, ἐκλείπειν μετὰ τὴν ἀνατολὴν, μιᾶς ὥρας ἱκανῶς παρελθούσης, καὶ ἐξέλιπεν ὅλη.

"Of the three ancient eclipses which we have taken from those observed in Babylon, the first is recorded as having occurred in the first year of MARDOCEMPADUS, according to [the reckoning of] the Egyptians on the 29th day of the month Thoth, toward the 30th. It began to be eclipsed, it is said, after its rising, when one hour had quite far passed, and the eclipse was total."

The term *ἱκανῶς παρελθούσης* seems to admit of some latitude of interpretation. PTOLEMY assumes the interval to be an hour and a half, HARTWIG an hour and a quarter. According to ZECH, the moon rose at $5^h\ 53^m$. PTOLEMY himself must be considered the best judge of the somewhat indefinite language used, and, on the other hand, the interval after moonrise was probably nearer one hour than two hours. I shall assume

a mean between an hour and a quarter and an hour and a half as the most probable interval, making:—

Babylon time of observed beginning	$7^h\ 15^m$
Correction for longitude	$2^h\ 56^m$
Greenwich mean time	$4^h\ 19^m$.

The probable error of this estimate I consider to be 12 minutes, the interval of time being so short as to admit of comparatively accurate estimate.

(2)

Η δὲ δευτέρα τῶν ἐκλείψεων ἀναγέγραπται γεγονυῖα τῷ δευτέρῳ ἔτει τοῦ αὐτοῦ Μαρδοκεμπάδου κατ' Αἰγυπτίους Θὼθ ιη εἰς τὴν ιθ. Εξέλιπε δέ, φησιν, ἀπὸ νότου δακτύλους τρεῖς αὐτοῦ τοῦ μεσονυκτίου.

"The second is recorded as having occurred in the second year of the same MARDOCEMPADUS, on the 18th of Thoth, toward the 19th. It was eclipsed from the south three digits in the middle of the night."

The indefiniteness of the time renders this eclipse of very little value for our present purposes.

The estimate of magnitude formerly served to determine the motion of the moon's node, but this can now be learned with far more accuracy from modern data So far as any indications are given, the middle of the eclipse was at midnight, a statement of which the probable error may be 40 minutes. We have, therefore:—

Greenwich apparent time of middle	$9^h\ 4^m \pm 40^m$
Equation of time	$+14^m$
Greenwich mean time	$9^h\ 18^m$.

(3)

Η δὲ τρίτη τῶν ἐκλείψεων ἀναγέγραπται γεγονυῖα τῷ αὐτῷ δευτέρῳ ἔτει τοῦ Μαρδοκεμπάδου κατ' Αἰγυπτίους Φαμενὼθ ιε εἰς τὴν ις. Ηρξατο δέ, φησιν, ἐκλείπειν μετὰ τὴν ἀνατολὴν, καὶ ἐξέλιπεν ἀπ' ἄρκτων πλεῖον τοῦ ἡμίσους.

"The third is recorded as having occurred in the same second year of MARDOCEMPADUS, the 15th of Phamenoth, toward the 16th. It began to be eclipsed, it is said, after the rising, and was eclipsed from the north more than the half."

The moon rose, according to ZECH, at $6^h\ 29^m$ local time, or $3^h\ 33^m$ Greenwich mean time. We can only conclude, from the data as expressed, that the eclipse had not become perceptible at this time; but, on the other hand, had the interval been considerable, say one hour or more, it would probably have been described. PTOLEMY supposes the interval half an hour I shall assume it to be 25 minutes, with a probable error of 20 minutes, which will make the

Greenwich mean time	$3^h\ 58^m \pm 20^m$.

(4) —620, April 21.

Τῷ γὰρ πέμπτῳ ἔτει Ναβοπολασσάρου, ὅ ἐστιν ρκζον ἔτος ἀπὸ Ναβονασσάρου, κατ' Αἰγυπτίους Αθὺρ κζ εἰς τὴν κη ὥρας ια ληγούσης, ἐν Βαβυλῶνι ἤρξατο ἡ σελήνη ἐκλείπειν, καὶ ἐξέλιπε τὸ πλεῖστον ἀπὸ νότου δ′ τῆς διαμέτρου.

"In the fifth year of NABOPOLASSAR, which is the 127th year from NABONASSAR according to the Egyptian reckoning, on the 27th of Athyr, toward the 28th, at the closing of the eleventh hour in Babylon, the moon began to be eclipsed, and was eclipsed mostly on the south a fourth of the diameter."

The time here indicated is 55 minutes before sunrise, which occurred at $17^h\ 36^m$ local apparent time, or the local mean time of beginning is $16^h\ 37^m$, the equation of time being -4^m; and the Greenwich mean time $13^h\ 41^m$. The probable error may be estimated at 15 minutes.

(5) —522, July 16.

Πάλιν δὴ τῷ ζ̄ῳ ἔτει Καμβύσου, ὅ ἐστι σκ̄ε^ον ἔτος ἀπὸ Ναβονασσάρου, κατ' Αἰγυπτίους Φαμενὼθ ιζ̄ εἰς τὴν ιη̄ πρὸ μιᾶς ὥρας τοῦ μεσονυκτίου, ἐν Βαβυλῶνι ἐξέλιπεν ἡ σελήνη ἀπ' ἄρκτων τὸ ἥμισυ τῆς διαμέτρου.

"In the seventh year of CAMBYSES, which is the 225th year from NABONASSAR, according to the Egyptians, on the 17th of Phamenoth, toward the 18th, one hour before midnight in Babylon, the moon was eclipsed from the north one half of her diameter."

We have then :—

Estimated local apparent time of middle of eclipse .	$11^h\ 10^m$
Equation of time	$-\ 1^m$
Greenwich mean time	$8^h\ 13^m \pm 24^m$.

A large uncertainty of phase is to be added to the probable error.

(6) —501, November 19.

Δευτέρα δὲ, ... γενομένη τῷ κ̄ ἔτει Δαρείου τοῦ μετὰ Καμβύσην, κατ' Αἰγυπτίους Επιφὶ κη̄ εἰς τὴν κθ̄, τῆς νυκτὸς προελθούσης ἰσημερινὰς ὥρας ς̄ γ″, καθ' ἣν ὁμοίως ἐξέλιπεν ἡ σελήνη ἀπὸ νότου τὸ δ″ τῆς διαμέτρου, ...

"The second eclipse happened in the 20th year of DARIUS, successor of CAMBYSES, on the 28th of Epiphi, toward the 29th, the night having advanced $6\frac{1}{3}$ equinoctial hours, the moon was eclipsed on the south $\frac{1}{4}$ of her diameter."

The sun set at $5^h\ 11^m$ apparent time; the equation of time being -13^m. The mean time here indicated is $11^h\ 18^m$, and the result is :—

Greenwich mean time of middle of eclipse . . . . $8^h\ 22^m \pm 25^m$.

(7) —490, April 25.

Ελάβομεν δὴ πρώτην μὲν ἔκλειψιν τὴν ἐπὶ Δαρείου τοῦ πρώτου τετηρημένην ἐν Βαβυλῶνι τῷ πρώτῳ καὶ τριακοστῷ αὐτοῦ ἔτει, κατ' Αἰγυπτίους Τυβί γ̄ εἰς τὴν δ̄, ὥρας ς̄ μέσης, καθ' ἣν διασαφεῖται ὅτι ἐξέλειπεν ἡ σελήνη ἀπὸ νότου δακτύλους β̄.

"We have taken an eclipse observed in the time of DARIUS the first in Babylon, in his 31st year, on the 3d, toward the 4th of Tybi, in which it is shown that in the middle of the sixth hour the moon was eclipsed two digits on the south."

The local apparent time here indicated is $11^h\ 28^m$, the equation of time -5^m, the Greenwich mean time $8^h\ 27^m$; probable error, 25 minutes.

(8) —382, December 22.

. . . . γεγονέναι δὲ τὴν πρώτην ἄρχοντος Αθήνησι Φανοστράτου, μηνὸς Ποσειδεῶνος, καὶ ἐκλελοιπέναι τὴν σελήνην βραχὺ μέρος τοῦ κύκλου, ἀπὸ θερινῆς ἀνατολῆς, τῆς νυκτὸς λοιποῦ ὄντος ἡμιωρίου. Καὶ ἔτι, φησὶν, ἐκλείπουσα ἔδυ.

"PHANOSTRATES being archon at Athens, the moon was eclipsed at Babylon in a small part of her orb, on the side of the summer rising, when one half hour of the night was still remaining, and the moon was still eclipsed when it set."

The first time here indicated is 36 minutes before sunrise, or $18^h\ 28^m$ local apparent time, and $18^h\ 31^m$ mean time. We have, therefore:—

Greenwich mean time of a small eclipse . . . . . . $15^h\ 35^m \pm 10^m$.

(9) —381, June 18.

Πάλιν τὴν ἑξῆς ἔκλειψίν φησι γεγονέναι ἄρχοντος Ἀθήνησι Φανοστράτου, Σκιροφοριῶνος μηνὸς, κατ' Αἰγυπτίους δὲ Φαμενὼθ κδ εἰς τὴν κε. Ἐξέλιπε δέ φησιν ἀπὸ θερινῆς ἀνατολῆς τῆς πρώτης ὥρας προεληλυθυίας. . . . Ἀλλ' ἐπεὶ ὁ πᾶς χρόνος τῆς ἐκλείψεως ὡρῶν τριῶν ἀναγράφεται, ...

"PHANOSTRATES being archon at Athens, on the 24th of Phamenoth, toward the 25th, it was said to be eclipsed on summer rising [at Babylon], the first hour being passed. The whole duration of the eclipse is recorded as three hours."

The date is —381, June 18. The sun set at $7^h\ 3^m$ apparent time, or $6^h\ 57^m$ mean time. The interval mentioned may be roughly estimated as something more than one equinoctial hour, say 1 hour and 7 minutes, with a probable error of 10 minutes.

We have, therefore:—

Local mean time [of beginning (?)] . . . . $8^h\ 4^m$
Greenwich mean time [of beginning (?)] . . . . $5^h\ 8^m$
Greenwich mean time of end . . . . $8^h\ 8^m$.

(10) —381, December 12, Babylon.

Ἐξέλιπε δέ, φησιν, ὅλη ἀρξαμένη ἀπὸ θερινῶν ἀνατολῶν δ ὡρῶν παρεληλυθυιῶν.

"It was said to be totally eclipsed, having begun on the summer rising, four hours having gone by."

The sun's semi-diurnal arc at Babylon was $5^h\ 5^m$, the length of the temporary hour was nearly $1^h\ 10^m$, the four temporary hours would have been nearly 4 hours 40 minutes; and as they had already passed, we may estimate the probable time at $4^h\ 50^m$ after sunset, with a probable error of 24 minutes. The equation of time being -3^m, we have:—

Local mean time of beginning . . . . $9^h\ 52^m$
Greenwich mean time of beginning . . . . $6^h\ 56^m$.

(11) —200, September 22.

. . . . καθ' ἣν ἤρξατο μὲν ἐκλείπειν ἡ σελήνη πρὸ ἡμιωρίου τῆς ἀνατολῆς, ἔσχατον δὲ ἀνεπληρώθη τρίτης ὥρας μέσης.

"The moon began to be eclipsed, on the one hand, half an hour before the rising, but was filled up again in the middle of the third hour."

If HIPPARCHUS is here fully and correctly quoted, which is very doubtful, he must have had a very indefinite idea of the difference between a calculated and an observed phenomenon, speaking as he does of an eclipse commencing half an hour before it was possible for the moon to be seen. Still, as the half hour is probably the result of an estimate from the magnitude of the eclipse at the time the moon first became visible, it is not without value. The moon rose at $6^h\ 0^m$ apparent time, which was $5^h\ 53^m$ mean time. The middle of the third hour was about $8^h\ 32^m$ apparent time, or $8^h\ 25^m$ mean time, making the Greenwich mean time of ending $6^h\ 25^m \pm 12^m$.

(12) — 199, March 19, Alexandria.

Ηρξατο δὲ τῆς νυκτὸς προελθουσῶν ὡρῶν ε̄ καὶ τριτημορίου, καὶ ἐξέλιπεν ὅλη.

"It began when $5\frac{1}{3}$ hours of the night were passed, and it was total."

This is $11^h\ 19^m$ apparent time, $11^h\ 29^m$ local mean time, and $9^h\ 29^m$ Greenwich mean time.

(13) — 199, September 11, Alexandria.

Ηρξατο δὲ τῆς νυκτὸς προελθουσῶν ὡρῶν ς̄ γ′ο, καὶ ἐξέλιπεν ὅλη. Καὶ τὸν μέσον δὲ τῆς ἐκλείψεως χρόνον φησὶ γεγονέναι περὶ ὥρας μάλιστα η̄ καὶ τριτημόριον, ...

"It began $6\frac{2}{3}$ hours of the night having passed, and it was total, and the middle of the eclipse arrived, he says about $8\frac{1}{3}$ hours of the night."

Here we have again, in the "middle of the eclipse", a time given which it was impossible to observe, without any indication of the data from which the time was derived. As the eclipse was total, the most natural data would have been the observed times of beginning and end of totality, which would be far more accurate than the observed times of beginning and ending of the partial phase. The times indicated are:—

Local apparent times	$12^h\ 41^m$ and $14^h\ 25^m$
Local mean times	$12^h\ 38^m$ and $14^h\ 22^m$
Greenwich mean times	$10^h\ 38^m$ and $12^h\ 22^m$.

(14) — 173, April 30, Alexandria.

Τῷ τοίνυν ζ̄ῳ ἔτει Φιλομήτορος, ὅ ἐστι φοδ̄ον ἀπὸ Ναβονασσάρου, κατ' Αἰγυπτίους Φαμενὼθ κζ̄ εἰς τὴν κη̄, ἀπὸ ὥρας η̄ ἀρχομένης ἕως ῑ ληγούσης, ἐν Ἀλεξανδρείᾳ ἐξέλιπεν ἡ σελήνη τὸ πλεῖστον ἀπ' ἄρκτων δακτύλους ζ̄.

"In the 7th year of PHILOMETER, which is the 574th from NABONASSAR, on the 27th of Phamenoth, toward the 28th, the moon was eclipsed in Alexandria from the beginning of the eighth hour to the close of the tenth, mostly on the north, seven digits."

These times are:—

Local apparent times	$12^h\ 54^m$ and $15^h\ 37^m$
Local mean times	$12^h\ 48^m$ and $15^h\ 31^m$
Greenwich mean times	$10^h\ 48^m$ and $13^h\ 31^m$.

(15) — 140, January 27, Rhodes.

Πάλιν δὴ τῷ λζ̄ῳ ἔτει τῆς τρίτης κατὰ Κάλιππον περιόδου, ὅ ἐστιν χζ̄ ἀπὸ Ναβονασσάρου, κατ' Αἰγυπτίους Τυβὶ β̄ εἰς τὴν γ̄, ὥρας ε̄ ἀρχομένης, ἐν Ῥόδῳ ἤρξατο ἐκλείπειν ἡ σελήνη καὶ ἐπεσκοτήθη τὸ πλεῖστον ἀπὸ νότου δακτύλους γ̄.

" . . . the 607th year from NABONASSAR [Egyptian reckoning], the second of Tybi, toward the third, at the beginning of the 5th hour in Rhodes, the moon began to be eclipsed, and was obscured, mostly on the south, three digits."

This is $9^h\ 42^m$ local apparent time, $10^h\ 0^m$ mean time, and $8^h\ 7^m$ Greenwich mean time.

(16) 125, April 5, Alexandria.

Δευτέραν δὲ τὴν τετηρημένην ἐν Ἀλεξανδρείᾳ, τῷ θ̅ ἔτει Ἀδριανοῦ, κατ᾽ Αἰγυπτίους Παχὼν ιζ̅ εἰς τὴν ιη̅, πρὸ τριῶν ὡρῶν ἰσημερινῶν καὶ τριῶν πέμπτων μιᾶς ὥρας τοῦ μεσονυκτίου, καθ᾽ ἣν ὁμοίως ἐξέλειπεν ἡ σελήνη τὸ ἕκτον μέρος τῆς διαμέτρου ἀπὸ μεσημβρίας.

"On the 17th of Pachon, toward the 18th, $3\frac{3}{5}$ equinoctial hours before midnight, the moon was eclipsed the sixth part of her diameter on the south."

This is 8^h 24^m apparent time, 8^h 26^m mean time, and 6^h 26^m Greenwich mean time.

(17) 133, May 6, Alexandria.

Πάλιν ὧν εἰλήφαμεν τριῶν ἐκλείψεων ἐκ τῶν ἐπιμελέστατα ἡμῖν ἐν Ἀλεξανδρείᾳ τετηρημένων, ἡ μὲν πρώτη γέγονε τῷ ιζ̅ ἔτει Ἀδριανοῦ, κατ᾽ Αἰγυπτίους Παϋνὶ κ̅ εἰς τὴν κα̅. Τὸν δὲ μέσον χρόνον ἀκριβῶς ἐπελογισάμεθα γεγονέναι πρὸ ἡμίσους καὶ τετάρτου μιᾶς ὥρας ἰσημερινῆς τοῦ μεσονυκτίου· καὶ ἐξέλιπεν ὅλη, καθ᾽ ἣν ὥραν ἀκριβῶς ἐπεῖχεν ὁ ἥλιος τοῦ ταύρου μοίρας ιγ̅ δ″ ἔγγιστα.

"Of the three eclipses which we have taken from those very carefully observed by us in Alexandria, the first occurred in the 77th year of HADRIAN, on the 20th of Payni, toward the 21st. We accurately noted the mid-time to have been one half and one fourth of an equinoctial hour before midnight, and it was wholly eclipsed."

The apparent precision with which the time is here expressed tends to inspire confidence, although we still have no data respecting the manner in which it was determined. The apparent time being 11^h 15^m, the local mean time is 11^h 8^m, the Greenwich mean time 9^h 8^m.

(18) 134, October 20, Alexandria.

Ἡ δὲ δευτέρα γέγονε τῷ ιθ̅ ἔτει Ἀδριανοῦ κατ᾽ Αἰγυπτίους Χοϊὰκ β̅ εἰς τὴν γ̅. Τὸν δὲ μέσον χρόνον ἐπελογισάμεθα γεγονέναι πρὸ α̅ ὥρας ἰσημερινῆς τοῦ μεσονυκτίου.

"The second occurred in the 19th year of HADRIAN, the 2d of Choïac toward the 3d: the mid-time we noted to have been one equinoctial hour before midnight, and it was eclipsed on the north one third of the diameter."

11^h apparent time is here 10^h 46^m mean time, and 8^h 46^m Greenwich mean time.

(19) 136, March 5, Alexandria.

Ἡ δὲ τρίτη τῶν ἐκλείψεων γέγονε τῷ κ̅ ἔτει Ἀδριανοῦ κατ᾽ Αἰγυπτίους Φαρμουθὶ ιθ̅ εἰς τὴν κ̅. Τὸν δὲ μέσον χρόνον ἐπελογισάμεθα γεγονέναι μετὰ δ̅ ὥρας ἰσημερινὰς τοῦ μεσονυκτίου· καὶ ἐξέλιπε τὸ ἥμισυ τῆς διαμέτρου ἀπ᾽ ἄρκτων.

"The third eclipse happened in the 20th year of HADRIAN, on the 19th of Pharmouthi, toward the 20th: the mid-time we noted to have been four equinoctial hours after midnight, and it was eclipsed the half of its diameter on the north."

16^h apparent time was then 16^h 14^m mean time, and 14^h 14^m Greenwich mean time.

This completes the series as given by PTOLEMY. The tabular positions of the sun and moon derived from HANSEN's tables for epochs of Greenwich mean time near the observed phases are shown in the following table. These places have all been computed in duplicate, the two computations being made by two separate computers. The motions in longitude are for 0.01 of a day, as the tables most conveniently give them. The motion in latitude is supposed to be $\frac{1}{11}$ that in longitude, positive at the ascending and negative at the descending node. The node can be identified by the value of $f + \omega$, which is the angular distance of the moon past the ascending node.

It may be remarked that the probable error of the longitude arising from the omission of the terms in the tables of double entry is about 24″.

Tabular Data for Eclipses of the Almagest.

No. of Eclipse.	Date.	Gr. M. T. of Computation.	Moon's Longitude.	14.4 l' Motion in $0^d.01$.	π Parallax.	β Latitude.	$f+\omega$	λ ☉'s Long. (HANSEN).	☉'s Semidiam.	14.4 λ' Motion in $0^d.01$.
		h m	° ′	′	′	° ′	°	° ′	′ ″	′
1	− 720, Mar. 19	5 0	170 59.3	7.57	55.7	+ 0 3.6	0.5	351 31.5	15 57	0.60
2	− 719, Mar. 8	8 0	160 30.4	7.10	53.9	+ 0 46.7	8.8	340 41.8	16 0	0.60
3	− 719, Sept. 1	3 0	329 55.4	9.08	61.2	− 0 37.8	187.6	150 54.4	16 0	0.58
4	− 620, Apr. 21	13 0	204 16.2	7.11	54.0	+ 0 52.8	169.8	24 23.6	15 49	0.59
5	− 522, July 16	8 0	286 37.2	7.18	54.2	− 0 40.9	352.2	106 33.2	15 48	0.57
6	− 501, Nov. 19	8 0	51 46.8	7.08	53.8	+ 0 50.7	170.2	231 54.2	16 16	0.60
7	− 490, Apr. 25	7 0	207 55.8	8.13	57.8	+ 1 1.6	168.1	28 31.4	15 49	0.59
8	− 382, Dec. 22	16 0	86 46.9	8.72	59.9	− 0 57.8	348.7	267 2.0	16 17	0.61
9	− 381, June 18	4 0	259 47.0	7.17	54.2	+ 0 46.5	171.2	80 27.8	15 45	0.57
10	− 381, Dec. 12	6 0	75 12.8	9.14	61.3	− 0 21.2	356.0	256 9.9	16 17	0.61
11	− 200, Sept. 22	5 0	356 20.4	7.48	55.4	+ 0 33.4	173.8	176 0.7	16 4	0.59
12	− 199, Mar. 19	8 0	173 56.4	8.28	58.3	+ 0 4.9	0.9	355 22.4	15 58	0.59
13	− 199, Sept. 11	10 0	343 55.1	8.33	58.5	+ 0 0.1	180.2	165 1.7	16 1	0.58
14	− 173, Apr. 30	10 0	214 45.9	9.07	61.1	− 0 35.7	186.8	35 40.1	15 49	0.57
15	− 140, Jan. 27	6 0	123 26.4	9.14	61.3	+ 0 46.6	8.9	304 31.9	16 12	0.60
16	+ 125, Apr. 5	6 0	194 2.6	8.31	58.4	+ 0 57.4	168.8	14 16.2	15 54	0.59
17	+ 133, May 6	8 0	223 56.1	7.33	54.8	− 0 25.7	355.1	44 11.5	15 48	0.58
18	+ 134, Oct. 20	8 0	25 54.9	7.56	55.7	− 0 26.8	185.2	206 15.1	16 11	0.60
19	+ 136, Mar. 5	12 0	163 51.8	8.89	60.5	− 0 53.2	349.7	344 36.9	16 2	0.60

Owing to the somewhat indefinite character of the data given by PTOLEMY, it will assist the judgment to present both his statements and the tabular results in a form in which they can be best compared. This is done in the following table, from which the reader can obtain a clear view of the comparison. The deduction of the numbers in the third and fourth columns has been given with the separate descriptions of the eclipses. They therefore need only these two remarks: (1) that the probable errors are the result of judgment from the terms of the description rather than of calculation; (2) that they were estimated without any knowledge of the way the comparison with theory would come out, and are printed without subsequent alteration.

In the column of "Phase described", Δ means magnitude of the eclipse. The tabular time of geometrical phase gives the time of beginning, middle, or end, as the case may be. The quantities Δ_1 and Δ_2 in the last column represent respectively the number of minutes a central eclipse may be supposed to have advanced before the observers would see it, and the number of minutes before the end that the observers lost sight of it. From eclipses (9), (13), and (14), the only ones of which both beginning

and end were observed, $\Delta_1 + \Delta_2$ comes out $- 10^m$. But they must both be positive, and this result only indicates that they are very small. I shall put conjecturally

$$\Delta_1 = 3^m$$
$$\Delta_2 = 2^m.$$

No. of Eclipse.	Date.	Greenwich Mean Time, indicated by PTOLEMY.	Prob. Error.	Phase described by PTOLEMY.	Tabular Duration.	Tabular Time of Geomet. Phase.	Corr. to Tabular Time.
		h m	m		h	h m	m
1	− 720, Mar. 19	4 19	12	Beginning .	3.8	4 11	$+ 8 - 1.0\Delta$
2	− 719, Mar. 8	9 18	40	Middle (?) .	1.9	8 15	$+ 63$
3	− 719, Sept. 1	3 58	20	Beginning .	2.4	3 15	$+ 43 - 1.5\Delta_1$
4	− 620, Apr. 21	13 41	15	Beginning .	1.0	12 57	$+ 44 - 3.8\Delta_1$
5	− 522, July 16	8 13	24	Middle (?) $\Delta = \frac{1}{2}$	2.6	8 0	$+ 13$
6	− 501, Nov. 19	8 22	24	Middle (?) $\Delta = \frac{1}{4}$	1.1	8 27	$- 5$
7	− 490, Apr. 25	8 27	24	Middle (?) $\Delta = \frac{2}{12}$	0.6	8 17	$+ 10$
8	− 382, Dec. 22	15 35	10	Small eclipse (commenc'g).	1.6	15 52	$- 17 - 2.2\Delta_1$
9	− 381, June 18	5 8	12	Beginning .	2.4	4 25	$+ 43 - 1.5\Delta_1$
		8 8	20	End . . .	2.4	6 51	$+ 77 + 1.5\Delta_2$
10	− 381, Dec. 12	5 56	24	Beginning .	3.4	5 57	$+ 59 - 1.1\Delta_1$
11	− 200, Sept. 22	3 23	39	Begin. (est.).	3.0	2 57	$+ 26$
		6 25	12	End . . .	. .	5 55	$+ 30 + 1.5\Delta_2$
12	− 199, Mar. 19	9 29	15	Beginning .	3.6	8 51	$+ 38 - 1.0\Delta_1$
13	− 199, Sept. 11	10 38	18	Beginning .	3.6	10 13	$+ 25 - 1.0\Delta_1$
		12 22	20	Middle . .	. .	12 3	$+ 19$
14	− 173, Apr. 30	10 48	20	Beginning .	2.7	10 4	$+ 44 - 1.4\Delta_1$
		13 31	20	End . . .	. .	12 45	$+ 46 + 1.4\Delta_2$
15*	− 140, Jan. 27	8 7	20	Beginning .	1.9	6 44	$+ 83 - 2.0\Delta_1$
16	+ 125, Apr. 5	6 26	18	Middle (?) $\Delta = \frac{1}{6}$	1.2	6 36	$- 10$
17	+ 133, May 6	9 8	12	Middle . .	3.5	8 38	$+ 30$
18	+ 134, Oct. 20	8 46	15	Middle . .	3.3	8 33	$+ 13$
19	+ 136, Mar. 5	14 14	15	Middle . .	2.2	13 26	$+ 48$

We shall now consider, seriatim, the conclusions that we may draw from the comparison.

1. The discordances of the times in the last column are, on the whole, not materially greater than would result from the probable errors in the fourth column. We therefore conclude that the probable errors have not been underestimated to any great extent.

2. There are five eclipses, namely, Nos. (2), (5), (6), (7), and (16), in which the phase is not expressly stated by PTOLEMY, but in which the middle of the eclipse has hitherto been supposed to be referred to. But, in the case of at least the last three, the tabular comparisons give color to the suspicion that it was really the time of beginning which was noted; and this suspicion is strengthened by the consideration that it was the time of beginning which was generally noted by the predecessors of

* ZECH supposes an error of an hour in the time of this eclipse. The alteration does not seem to me justified by the discordance of two and a half times the probable error.

PTOLEMY. I therefore deem it advisable to reject these five eclipses, owing to the uncertainty of the phase noted. Quite accordant results might be obtained by supposing that the beginning was observed in some cases and the end in others; but the uncertainty is too great to justify this course.

3. The question whether eclipse No. (8) was really seen is a very serious one. When we take out the five doubtful eclipses and this one, seventeen observations of phase are left, every one of which indicates a positive correction to the tabular time; and the results throughout the nine centuries over which the records extend are so accordant that I do not see how the reality of this correction can be doubted. The serious point is not simply that No. (8) gives a negative result, for this might arise from accidental errors of observation, but that a positive correction to the time will render the eclipse absolutely invisible at Babylon. In fact, the account says that there was a small eclipse (not simply that the eclipse was beginning) half an hour before sunrise. At this time, however, the twilight would have been so bright and the altitude of the moon so low that the eclipse could not be seen for a number of minutes after its commencement. On the other hand, the tabular time indicates that the eclipse did not commence geometrically until about nineteen minutes before sunrise; and, in this case, the eclipse could scarcely have been seen at all, because the constantly increasing light and the constantly diminishing altitude of the moon would have drowned out the slowly increasing eclipse. In fact, when the sun rose, the moon would have been eclipsed only about 3′, or one tenth of her diameter. If, again, we take the tabular correction indicated by the other eclipses, we find that the eclipse did not begin until some time after the moon had set.

We have therefore this dilemma: either there is a mistake about the eclipse of −382, December 22, having been really observed at Babylon, or the seventeen good observations of phases cited by PTOLEMY are systematically in error by nearly half an hour. I cannot hesitate in accepting the former as the most probable alternative. The occurrence of the eclipse being expected, it is quite possible that the observers may have thought they saw the moon eclipsed in the increasing daylight, when there was really no eclipse; or, under the unfavorable circumstances, they might have been deceived by a dark region of the lunar disk being near the moon's limb. Nor can a mistake of date be regarded as out of the question. On the whole, I think that this eclipse should be rejected, since, if we regard it as a real observation, the results from the other eclipses must be regarded as all wrong.

We have left thirteen eclipses, of four of which two phases, beginning and end, were observed or estimated. We next divide these into groups, and take the mean by weights, derived approximately from the probable errors in the fourth column.

From eclipses (1), (3), and (4), giving them the respective weights 3, 1, and 2, we find:—

$$\text{Epoch } -687,\ \Delta T = +26^{\text{m}} - 2.0\,\Delta_1 = +20^{\text{m}} \pm 8^{\text{m}}.$$

From (9) and (10), with the weights 8, 3, and 2, we find:—

$$\text{Epoch } -381,\ \Delta T = +53^{\text{m}} - 1.1\,\Delta_1 + 0.3\,\Delta_2 = 50^{\text{m}} \pm 9^{\text{m}}.$$

From (11) to (15) inclusive, giving the phases weights 1, 6, 4, 3, 2, 2, 2, 2:—

$$\text{Epoch } -189,\ \Delta T = +37^{\text{m}} - 0.6\,\Delta_1 + 0.6\,\Delta_2 = +36^{\text{m}} \pm 6^{\text{m}}.$$

From (17) to 19), giving the weights 3, 2, 2:—

$$\text{Epoch } + 134, \ \varDelta T = + 30^{m} \pm 8^{m}.$$

If we reduce these results to minutes of arc, we find the following corrections to the moon's mean longitude, as derived from HANSEN's Tables:—

Epoch.	$\delta\varepsilon$.	Wt.
-687	$-11' \pm 4'$	3
-381	$-27' \pm 5'$	2
-189	$-20' \pm 3'$	4
$+134$	$-16' \pm 4'$	3

In the light of these comparisons with theory, we could no doubt amend some of our interpretations of the times given by PTOLEMY. PTOLEMY's interpretation of the description of the first eclipse would seem to be more correct than the one adopted, while, in the case of eclipse (9), it was an error to suppose that much more than an hour had passed. But, although, by thus amending the interpretations, a better agreement would be attained among the observations, I do not think the final result would be improved, and it certainly would not be materially altered. I think we may conclude, with a high degree of probability, that during the eight centuries preceding the Christian era the mean longitude of the moon in HANSEN's Tables requires a correction of about $+18'$.*

§ 5.

ARABIAN OBSERVATIONS OF ECLIPSES, EXTRACTED FROM CAUSSIN'S TRANSLATION OF EBN JOUNIS.

The complete French title of this work is, "*Le Livre de la grande Table Hakémite observée par le Sheikh, l'Imam, le docte, le savant Aboulhassan Ali ebn Abderrahman, ebn Ahmed, ebn Jounis, ebn Abdalaala, ebn Mousa, ebn Maïsara, ebn Hafes, ebn Hiyan. Traduit par le C.en* CAUSSIN, *professeur de la langue Arabe au Collège de France.* A Paris, de l'imprimerie de la République. An xii. [1804, v. s.]."

Most of the observations which will be quoted were also published, before the appearance of the book, in the Memoirs of the Paris Academy of Sciences, vol. 2; and there are a few discrepancies between the results there given and those in the extended work. I shall, however, use the latter as my authority.

The ideas of the author respecting the errors of instruments seem to have been far ahead of his age, if we may judge from the following description of the precautions which must be taken to obtain good observations. Unfortunately, only a fraction of the observations could have been made by this most critical observer, who died in 1008.

"*De l'Erreur des Instrumens qui servent à mesurer.*

"L'art ne pouvant atteindre, dans la fabrication des instrumens, la justesse qui conçoit l'esprit de l'artiste, soit pour égaliser leur surfaces, soit pour les diviser et

* Since reaching this conclusion, I have been strongly inclined to think that the phases recorded should be considered as geometrical contacts, and therefore that Δ_1 and Δ_2 should both be regarded as zero. This change would make the results slightly more consistent, and would increase the tabular correction from the first group of observations. I have not, however, considered it advisable to introduce it.

les centrer avec précision, il faut nécessairement qu'ils soient sujets à des erreurs provenant de quelqu'une de ces causes ou de leur situation par rapport à l'horizon. S'il y a une construction, elle est sujet à des dévers ou apparens ou insensibles; si les instrumens sont de bois, le bois se gauchit, sur-tout s'il est fixé dans un lieu exposé au soleil et à l'humidité. Il y aura toujours d'autant moins d'erreurs dans les instrumens, qu'ils auront été construits par un homme plus instruit, plus habile et plus attentif. A ce que je viens de dire, il faut ajouter, dans l'observateur, l'habitude d'observer, de placer d'aplomb, la justesse de l'aplomb lui-même, &c. S'imaginer que chacun est en état de prendre toute espèce de mesure sans en avoir l'habitude, et que tous les instrumens donnent des résultats sûrs, c'est être dans l'erreur. Celui qui veut faire de bonnes observations, doit s'appliquer long-temps à connoître les instrumens et s'accoutumer à s'en servir."

The geographical position of Bagdad does not seem to be very well determined, but the observations with which we have to deal are so rough that the probable error is not of importance in the present investigation. The latest determinations I can find are in the *Connaissance des Temps* for 1836, *Additions*, p. 138, where the latitude, $33^\circ\ 19'\ 50''$, is taken from a paper by BEAUCHAMP in ZACH'S *Monatliche Correspondenz*, vol. i, and the longitude is taken from a note to the same paper. The following appear to be the results of the separate determinations:—

Conn. des Temps for 1788 . . .	$\lambda = 2^h\ 48^m\ 18^s$	Source unknown.
BEAUCHAMP, *Mon. Corr.*, vol. i, p. 65	$2^h\ 48^m\ 9^s$	Eclipse Jup. III. Sat.
BEAUCHAMP, *Mon. Corr.*, vol. i, p. 65	$2^h\ 47^m\ 38^s$	Eclipse Jup. I. Sat.
TRIESNECKER, *Mon. Corr.*, vol. i, p. 65	$2^h\ 48^m\ 9^s$	Eclipse ⊙, June 3, 1788.

These longitudes are counted from Paris. I have adopted the last result, which is that employed in the recent volumes of the *Connaissance des Temps*, assuming

Latitude of Bagdad . . . . $33^\circ\ 20'$
Longitude east of Greenwich . . . . $2^h\ 57^m\ 30^s$.

The longitude may be considered as subject to a probable error of ten or fifteen seconds, which is not of importance at present.

The position of Cairo is also taken from recent numbers of the *Connaissance des Temps*, as follows:—

Latitude . . . . $30^\circ\ 2'$
Longitude from Paris . . . . $1^h\ 55^m\ 41^s$;

whence,

Longitude from Greenwich . . . . $2^h\ 5^m\ 2^s$.

We shall first copy the descriptions of the observations from the work in question, and then present the results in a tabular form as far as possible. Eclipses in which the data are entirely insufficient will be passed over in silence.

(1) Page 84.—"*Éclipse de soleil observée à Bagdad le* 30 [29] *novembre* 829. Hauteur du soleil au commencement, selon le rapport des astronomes, 7°; hauteur à la fin, 24°, sur les trois heures du jour environ."

The local mean times hence deduced are:—

Beginning	$19^h\ 33^m\ 44^s$
End	$21^h\ 24^m\ 24^s$.

(2) Page 88.—"*Éclipse de lune observée à Bagdad le* 12 [11] *août* 854. On observa au commencement de l'éclipse, la hauteur d'Aldébaran de 45° 30′ à l'orient: on n'observa point d'autre instant ni d'autre circonstance de cette éclipse que l'instant du commencement, qui est exact et précis."

Result: Local mean time of beginning . . . . $14^h\ 58^m\ 37^s$.

(3) Page 90.—"*Éclipse de lune observée à Bagdad le* 22 [21] *juin* 856. On observa au commencement de l'éclipse la hauteur d'Aldebaran de 9° 30′ à l'orient."

Result: Local mean time of beginning . . . . $15^h\ 19^m\ 28^s$.

(4) Page 112.—"*Éclipse de lune observée à Bagdad le* 1 *juin* 923. * * la fin à 3^h, heures égales; hauteur de l'étoile près de la queue du Cygne [α Cygni], 29° 30′ à l'orient."

Result: Mean time of end . . . . $9^h\ 54^m\ 3^s$.

(5) Page 114.—"*Éclipse de soleil observée à Bagdad le* 11 [10] *novembre* 923. Nous nous réunîmes plusieurs pour l'observer et nous distinguâmes clairement ses circonstances. Hauteur du soleil au milieu de l'éclipse déterminée d'après l'estime de tous les observateurs, 8° orient; la fin à $2^h\ 12^m$, heures inégales; la hauteur alors de 20°."

Result: Local mean time of middle	$19^h\ 19^m\ 38^s$
Local mean time of end	$20^h\ 30^m\ 2^s$.

Of course, the first observation can have no astronomical value.

(6) Page 116.—"*Éclipse de lune observée à Bagdad le* 11 *avril* 925. J'ai observai cette éclipse et j'ai trouvé au commencement la hauteur d'Arcturus de 11° à l'orient; hauteur de l'étoile Wega, à la fin, 24°. Le commencement, d'après cette observation, arriva à 55′, heures inégales, de la nuit; * * la fin, selon l'observation, $4^h\ 36^m$, heures inégales."

Result: Mean time of beginning	$5^h\ 36^m\ 6^s$
Mean time of end	$10^h\ 45^m\ 19^s$.

There is clearly an error in the statement that the altitude of Arcturus was 11° at the beginning of the eclipse; it must have been 30° or upward. I cannot see that any other bright star could have had an altitude of 11° at the time in question, while Arcturus was far the most prominent star in the east. It, therefore, seems probable that the altitude is incorrectly given. We shall, therefore, endeavor to deduce the time from the results of the Arabian calculations, checking the latter by comparison with our own. The sun was in about 10° north declination; the geometrical setting of his centre, therefore, occurred at $6^h\ 26^m$ apparent time, or $6^h\ 25^m$ mean time, and each temporary hour measured about $55^m.7$. The interval given by the Arabians

corresponds to $4^h\ 16^m.2$ mean time, making their computed time of ending $10^h\ 41^m.2$, showing an error of four minutes, which would be diminished if we suppose that they applied semidiameter and refraction in computing the time of sunset. (It will be noted that we here have to do with a computed, and not with an observed, sunset.) Now, for the beginning of the eclipse, $55'$ corresponds to $51^m.0$ of mean time, making their computed time of beginning $7^h\ 16^m.0$. Applying the correction of $4.^m1$, we have:—

Probable mean time of beginning . . . . $7^h\ 20^m.1$.

This result will be subject to an error, arising from the error in the relative positions of Arcturus and α Lyræ adopted by the Arabians. The probable amount of this error will not, I conceive, exceed two or three minutes of time.

(7) Page 118.—"*Éclipse de lune observée à Bagdad le* 14 [13] *septembre* 927. Le commencement à $10^h\ 14^m$ de la nuit de vendredi, le milieu à $11^h\ 21^m$, la fin à 9^m du jour de vendredi, le tout en heures inégales. Cet éclipse, dit-il, fut observée par mon fils Aboulhassan. Hauteur de Sirius au commencement, 31° à l'orient; révolution de la sphère depuis le coucher du soleil jusqu'au commencement de l'éclipse, déterminée avec l'astrolabe, 148° environ."

From what follows, it appears that the times given are those computed from the tables. From the altitude of Sirius we have:—

Local mean time of beginning . . . . $15^h\ 48^m\ 16^s$.

The observation with the astrolabe gives a result only one or two minutes later.

(8) Page 120.—"*Éclipse de soleil observée à Bagdad le* 18 [17] *août* 928. Le soleil se leva éclipsé d'un peu moins du quart de sa surface. * * * Nous observâmes le soleil dans l'eau d'une manière sûre et distincte. Nous trouvâmes à la fin lorsqu'aucune partie du soleil n'étoit plus éclipsée, et que son disque paroissoit entier dans l'eau, la hauteur de 12° à l'orient, moins le tiers d'une division de l'instrument divisé par tiers de degré, ce qui fait retrancher $\frac{1}{9}$ de degré. (Hauteur, 11° 53′ 20″.)"

Result: Mean time of end . . . . $18^h\ 26^m\ 59^s$.

(9) Page 122.—"*Éclipse de lune observée à Bagdad le* 27 *janvier* 929. J'ai observé, dit-il, le commencement de cette éclipse. La hauteur d'Arcturus étoit alors 18° à l'orient."

Result: Local mean time of beginning . . . . $11^h\ 3^m\ 2^s$.

(10) Page 124.—"*Éclipse de lune observée à Bagdad le* 5 [4] *novembre* 933. J'ai observé, dit-il, cette éclipse lorsque la lune commença à s'obscurcir. La hauteur d'Arcturus étoit alors 15° à l'orient."

Result: Local mean time . . . . $16^h\ 15^m\ 15^s$.

The remaining eclipses were observed at Cairo.

(11) Page 164.—"*Éclipse de soleil observée au Caire le* 12 *décembre* 977. Chacun attendoit le commencement de l'éclipse; elle parut sensible à la vue lorsque la hauteur

du soleil étoit entre 15 et 16 degrés. * * * Le soleil parut reprendre toute sa clarté; et je trouva sa hauteur 33° 20′ environ, chacun étant d'accord de la fin de l'éclipse."

Result:	The eclipse sensible to the view	$20^h\ 24^m\ 4^s$
	No longer visible	$22^h\ 41^m\ 12^s$.

(12) Page 166.—"*Éclipse de soleil observée au Caire le* 8 *juin* 978. Hauteur du soleil, lorsque l'éclipse commença à être sensible aux yeux, 56° environ; hauteur à la fin, 26° environ."

Result:	The eclipse sensible to the view	$2^h\ 27^m\ 31^s$
	The eclipse ended	$4^h\ 47^m\ 15^s$.

(13) Page 168.—"*Éclipse de lune observée au Caire le* 14 *mai* 979. La fin de l'éclipse à une heure 12′ de la nuit, heures égales."

Here we have to accept the results of the Arabian astronomer without any of the data by which he determined his time.* The geometrical setting of the sun's centre was at $6^h\ 49^m$ apparent time, and $6^h\ 43^m$ mean time If we allow 2 minutes for refraction, it will make the mean time of commencement $7^h\ 57^m$, a result which is uncertain by several minutes.

(14) Page 168.—"*Éclipse de soleil observée au Caire le* 28 *mai* 979. Hauteur du soleil lorsque l'éclipse fut sensible à la vue, 6° 30′. Le soleil se coucha éclipsé."

Result: The eclipse sensible to the sight . . . . . . $6^h\ 18^m\ 0^s$.

(15) Page 168.—"*Éclipse de lune observée au Caire le* 7 [6] *novembre* 979. Hauteur au commencement, 64° 30′ orient; hauteur à la fin, 65° occident, environ."

Result, supposing the altitudes to be those of the moon, which is not distinctly stated:—

Beginning	$10^h\ 9^m\ 50^s$
End	$13^h\ 22^m\ 46^s$.

(16) Page 170.—"*Éclipse totale de lune observée au Caire le* 3 [2] *mai* 980. Hauteur de la lune au commencement, 47° 40′; la fin, 36′ environ, heures égales, avant la fin de la nuit."

This altitude of the moon assigned by the observation exceeds the actual meridian altitude, so that there is some mistake which prevents the beginning being used. For the end we have:—

Apparent time of sunrise, ☉'s declination being 17°.0 .	$17^h\ 19^m.4$
The interval as given by the Arabs	$-\ 36^m.0$
Equation of time	$-\ 5^m.3$
Longitude	$-\ 2^h\ 5^m.0$
Greenwich mean time of ending	$14^h\ 33^m.1$.

*After completing the discussion of these eclipses, I am inclined to suspect that this may be a calculated and not an observed time. As the result would not be appreciably altered by the suppression of the observation, I have let the eclipse remain.

(17) Page 170.—"*Éclipse de lune observée au Caire le* 22 [21] *avril* 981. Hauteur de la lune au commencement, 21° environ; grandeur, le quart du diamètre environ; fin de l'éclipse, un quart d'heure environ avant le lever du soleil."

Local mean time of beginning		$15^h\ 28^m\ 38^s$
For the end we have app. time of sunrise (Dec. $= + 13°.8$)		$17^h\ 27^m.4$
Interval as given	—	15^m
Equation of time	—	$3^m.7$
Longitude	—	$2^h\ 5^m.0$
Greenwich mean time of end		$15^h\ 3^m.7$.

(18) Page 170.—"*Éclipse de lune observée au Caire le* 15 *octobre* 981. Grandeur de l'éclipse, 5 doigts environ du diamètre; hauteur de la lune lors de l'attouchment par dehors, selon mon évaluation, 24°."

Local mean time of beginning . . . . $16^h\ 18^m\ 15^s$.

(19) Page 172.—"*Éclipse totale de lune observée au Caire le* 1 *mars* 983. Hauteur de la lune lorsque l'éclipse parut sensible, 66°; hauteur lorsque la lune eut repris sa clarté, 35° 50′; durée de l'éclipse totale une heure, environ."

Here, again, the first altitude assigned is impossible. From the second we deduce:—

Local mean time of ending . . . . $15^h\ 38^m\ 0^s$.

(20) Page 172—"*Éclipse de soleil observée au Caire le* 20 *juillet* 985. Hauteur du soleil au commencement de l'éclipse, 23° environ; hauteur à la fin, lorsque l'éclipse n'étoit plus sensible à la vue, 6°; grandeur de l'éclipse, un quart du diamètre."

Local mean time of beginning	$5^h\ 1^m\ 32^s$
Local mean time of end	$6^h\ 23^m\ 15^s$.

(21) Page 172.—"*Éclipse de lune observée au Caire le* 19 [18] *décembre* 986. Hauteur de la lune au commencement de l'éclipse visible, 24° occident. J'ai évalué la hauteur au moment de l'attouchement, 50° 30′; grandeur, 10 doigts du diamètre. La lune se coucha éclipsée."

I can give no explanation of this second observation. From the first altitude we have:—

Local mean time of commencement . . . . $16^h\ 56^m\ 4^s$.

(22) Page 174.—"*Éclipse de lune observée au Caire le* 12 *avril* 990. Hauteur de la lune, au commencement, je veux dire, au moment de l'attouchement, 38°."

Local mean time of "attouchement" . . . . $9^h\ 45^m\ 59^s$.

(23) Page 174—"*Éclipse de soleil observée au Caire le* 20 [19] *août* 993. Hauteur du soleil, au commencement de l'éclipse, 27° orient; hauteur au moment de la plus grande phase, 45° orient; hauteur à la fin, 60° orient; grandeur, $\frac{2}{3}$ de la surface."

Result: Mean time of commencement	$19^h\ 41^m\ 23^s$
Mean time of the end	$22^h\ 22^m\ 37^s$.

(24) Page 176.—"*Éclipse totale de lune observée au Caire le* 1 *mars* 1002. L'éclipse fut totale avec demeure dans l'ombre. Hauteur d'Arcturus au commencement, 52° orient; hauteur de l'étoile α du cocher, 14° occident; hauteur d'Arcturus à la fin, 35°."

On these inconsistent altitudes of Arcturus, Caussin remarks that the altitude at commencement may be either 12° or 52°, but Bouvard advised him that the latter reading must be taken. The last altitude of Arcturus, 35°, admits of no doubt in reading. The star which had the altitude 14° is also doubtful, the name given in the manuscript not being found in the Arabian Star Catalogues; but he found a similar name in Scaliger as pertaining to α Aurigæ.

The results for beginning are:—

From altitude of Arcturus	$11^h\ 41^m\ 23^s$
From altitude of α Aurigæ	$11^h\ 45^m\ 40^s$
Adopted result	$11^h\ 43^m\ 2^s$.

(25) Page 178.—"*Éclipse de soleil observée au Caire le* 24 [23] *janvier* 1004. Grandeur de l'éclipse, 11 doigts; hauteur du soleil, lorsque l'éclipse commença à paroître sur son disque, 16° 30′ occident; commencement estimé à 18° 30′; hauteur lorsque le quart du diamètre étoit éclipsé, 15°; hauteur lorsque la moitié du diamètre fut éclipsée, 10°; hauteur au moment de la plus grande phase, 5°."

The difference of the first two altitudes is surprising, corresponding as it does to 11 minutes of time. The results are:—

The eclipse sensible	$4^h\ 6^m\ 13^s$
Estimated time of beginning	$3^h\ 55^m\ 17^s$.

The local mean times have been reduced to Greenwich mean time by applying the longitudes already given, and the results are shown in tabular form in the following pages. The tabular geocentric positions of the moon are first given, the times of computation being generally nearly the same with those of observation. In computing the longitudes, the double-entry tables have been omitted and the constant 22240 added, a proceeding which involves a mean error of $\pm 14''$ in the longitudes. The moon's motion in latitude is omitted; it will be sufficient to suppose it equal to $\frac{1}{11}$ the motion in longitude. Its algebraic sign is, however, given immediately after the latitude itself.

Respecting the places of the sun, it is only necessary to say that they are from Hansen's Tables.

Tabular Positions of the Moon and the Sun for the Arabian Observations.

No. of Eclipse.	Date and Place.	t_0 Gr. M. T. of Computation.	λ_0 Moon's Longitude.	Mot. in $0^d.01$.	β_0 Latitude: increasing + diminishing −	π Parallax.	The Sun's Longitude.	Log. of Radius vector.	Semi-diam.
	Bagdad.								
		h m s	° '	'	'	'	° '		'
1	829, Nov. 29	16 36 14	251 37.6	7.86	+ 22.1 −	56.9	252 37.0	9.99270	16.2
		18 26 54	252 38.1	7.87	+ 16.8 −	56.9	252 41.7	9.99269	16.2
☽ 2	854, Aug. 11	12 1 7	321 40.3	8.81	+ 18.3 +	60.3	142 35.4	. . .	15.9
☽ 3	856, June 21	12 21 58	273 34.5	8.25	− 45.2 +	58.2	94 10.6	. . .	15.7
☽ 4	923, June 1	6 56 33	255 29.8	8.60	− 43.8 −	59.6	74 43.4	. . .	15.8
5	923, Nov. 10	16 21 8	232 37.3	9.07	+ 32.4 −	61.3	233 26.8	9.99355	16.2
		17 32 32	233 22.4	9.07	+ 28.2 −	61.2	233 29.8	9.99354	16.2
☽ 6	925, April 11	2 38 36	204 16.7	8.43	+ 36.8 −	59.0	26 8.0	. . .	15.9
		7 47 49	207 18.5	8.46	+ 20.1 −	59.1	26 20.5	. .	15.9
☽ 7	927, Sept. 13	12 50 46	354 28.7	9.09	+ 51.2 +	61.3	175 12.0	. . .	16.0
8	928, Aug. 17	15 29 29	149 7.5	7.86	− 13.1 −	56.9	149 37.0	0.00304	15.9
☽ 9	929, Jan. 27	8 5 32	131 48.5	8.51	+ 30.6 −	59.3	313 14.1	. . .	16.2
☽ 10	933, Nov. 4	13 17 45	46 54.7	7.24	− 5.9 −	54.5	227 48.8	. . .	16.2
	Cairo.								
11	977, Dec. 12	18 19 2	265 49.0	9.11	+ 35.2 −	61.4	267 1.7	9.99106	16.3
		20 36 10	267 16.1	9.11	+ 27.3 −	61.4	267 7.5	9.99105	16.3
12	978, June 8	0 22 29	81 58.5	7.10	− 6.2 +	54.0	81 48.9	0.00735	15.7
		2 42 13	83 7.3	7.10	+ 0.3 +	54.0	81 54.4	0.00735	15.7
☽ 13	979, May 14	5 52 0	238 51.2	8.30	+ 32.5 −	58.5	57 57.0	. . .	15.8
14	979, May 28	4 12 58	71 47.5	7.61	+ 39.0 +	55.9	71 15.1	0.00713	15.8
☽ 15	979, Nov. 6	8 3 40	48 42.7	8.31	− 37.6 +	58.6	229 27.1	. . .	16.2
		11 18 0	50 34.8	8.29	− 27.2 +	58.5	229 35.3	. . .	16.2
☽ 16	980, May 2	14 26 0	228 24.4	7.47	− 12.0 −	55.4	47 31.3	. . .	15.8
☽ 17	981, April 21	13 28 0	216 14.9	7.09	− 45.9 −	53.9	36 40.0	. . .	15.9
☽ 18	981, Oct. 15	14 7 0	27 24.4	9.03	+ 46.6 +	61.1	208 1.6	. . .	16.1
☽ 19	983, Mar. 1	9 55 0	165 18.7	8.64	+ 31.9 −	59.7	346 13.3	. . .	16.1
		13 40 0	167 33.5	8.61	+ 19.4 −	59.6	346 22.6	. . .	16.1
20	985, July 20	2 56 30	122 43.3	8.17	+ 15.0 −	58.0	122 17.6	0.00587	15.8
		4 18 13	123 29.7	8.18	+ 10.9 −	58.1	122 20.9	0.00587	15.8
☽ 21	986, Dec. 18	14 53 0	92 16.9	7.10	+ 30.3 −	54.0	272 49.4	. . .	16.3
☽ 22	990, April 12	7 42 0	206 43.9	7.10	− 37.5 +	54.0	27 34.2	. . .	15.9
		11 4 0	208 23.4	7.10	− 28.3 +	53.9	27 42.4	. . .	15.9
23	993, Aug. 19	17 36 5	150 28.6	9.04	+ 5.3 +	61.1	151 54.6	0.00288	15.9
☽ 24	1002, Mar. 1	9 41 18	165 37.4	9.13	− 12.1 −	61.4	346 36.0	. . .	16.1
25	1004, Jan. 24	1 51 0	310 9.4	8.39	+ 15.8 +	58.8	308 43.3	9.99444	16.2

Comparison of Tabular and Observed Times for the Arabian Observations.

o. of Eclipse.	Date and Place.	Phenomenon Observed.	Local M. T. Obs.	Gr. M. T. of Obs.	Tabular Gr. Time of Geomet. Phase.	Δt	F	Δl	Class.
	Bagdad.		h m s	h m s	h m s	m			
1	829, Nov. 29	☉ Beginning .	19 33 44	16 36 14	15 50 20	+ 45.9	0.51	− 23.2	*a*
		☉ Ending . .	21 24 24	18 26 54	18 8 56	+ 18.0	0.42	− 7.6	*b*
2	854, Aug. 11	☽ Beginning .	14 58 37	12 1 7	11 53 59	+ 7.1	0.51	− 3.6	*b*
3	856, June 21	☽ Beginning .	15 19 28	12 21 58	12 18 13	+ 3.7	. .	− 1.9	*a*
4	923, June 1	☽ Ending . .	9 54 3	6 56 33	6 49 49	+ 6.7	. .	− 3.4	*a*
5	923, Nov. 10	☉ Ending . .	20 30 2	17 32 32	17 15 50	+ 16.7	0.40	− 6.7	*b*
6	925, Apr. 11	☽ Beginning .	7 20 6	4 22 36:	4 27 8	− 4.5	0.51	+ 2.3	*c*
		☽ Ending . .	10 45 19	7 47 49	7 45 35	+ 2.2	. .	− 1.1	*a*
7	927, Sept. 13	☽ Beginning .	15 48 16	12 50 46	13 4 1	− 13.2	. .	+ 6.7	*b*
8	928, Aug. 17	☉ Ending . .	18 26 59	15 29 29	15 19 26	+ 10.0	0.45	− 4.5	*a*
9	929, Jan. 27	☽ Beginning .	11 3 2	8 5 32	9 4 20	− 58.8	0.51	+ 29.7	*a*
10	933, Nov. 4	☽ Beginning .	16 15 15	13 17 45	13 15 54	+ 1.8	. .	− 0.9	*a*
	Cairo.								
11	977, Dec. 12	☉ Beginning (S.)	20 24 4	18 19 2	18 10 30	+ 8.5	0.37	− 3.2	*b*
		☉ Ending . .	22 41 12	20 36 10	20 33 0	+ 3.2	0.35	− 1.1	*b*
12	978, June 8	☉ Beginning (S.)	2 27 31	0 22 29	23 57 47	+ 24.7	0.28	− 6.9	*a*
		☉ Ending . .	4 47 15	2 42 13	2 38 20	+ 3.5	0.48	+ 1.9	*a*
13	979, May 14	☽ Ending . .	7 57 2	5 52 0	5 40 44	+ 11.3	0.51	− 5.8	*c*
14	979, May 28	☉ Beginning (S.)	6 18 0	4 12 58	4 2 38	+ 10.2	0.52	− 5.3	*a*
15	979, Nov. 6	☽ Beginning .	10 9 50	8 4 48	8 1 26	+ 3.4	0.51	− 1.7	*b*
		☽ Ending . .	13 22 52	11 17 50	11 3 55	+ 13.9	. .	− 7.0	*b*
16	980, May 2	☽ Beginning .	. . . .	☽ too high	10 39 0	. .	. .	. .	.
		☽ Ending . .	16 38 8	14 33 06	14 28 19	+ 4	. .	− 2.4	*c*
17	981, Apr. 21	☽ Beginning .	15 28 42	13 23 40	13 20 50	+ 2.8	. .	− 1.4	*c*
		☽ Ending . .	17 8 44	15 3 42	15 5 18	− 1.6	. .	+ 0.8	*c*
18	981, Oct. 15	☽ Beginning .	16 18 15	14 13 13	13 58 25	+ 14.8	. .	− 7.7	*b*
19	983, Mar. 1	☽ Beginning (S.)	. . . .	too high	9 59 39	. .	. .	. .	.
		☽ Ending . .	15 37 58	13 32 56	13 15 14	+ 17.7	. .	− 8.9	*a*
20	985, July 20	☉ Beginning .	5 1 32	2 56 30	2 32 10	+ 24.3	0.43	− 10.6	*c*
		☉ Ending . .	6 23 15	4 18 13	4 3 32	+ 14.7	0.62	− 9.1	*c*
21	986, Dec. 18	☽ Beginning (S.)	16 56 6	14 51 4	14 28 56	+ 22.1	0.51	− 11.2	*a*
22	990, Apr. 12	☽ Beginning (at)	9 45 59	7 40 57	8 6 9	− 25.2	. .	+ 12.8	*b*
23	993, Aug. 19	☉ Beginning .	19 41 23	17 36 21	17 36 1	+ 0.3	0.41	− 0.1	*a*
		☉ Ending . .	22 22 37	20 17 35	19 57 43	+ 19.9	0.51	− 10.2	*c*
24	1002, Mar. 1	☽ Beginning .	11 43 2	9 38 0	9 35 28	+ 2.5	. .	− 1.3	*a*
		☽ Ending . .	. . . .	unavailable	12 59 2	. .	. .	. .	.
25	1004, Jan. 24	☉ Beginning (est.)	3 55 17	1 50 15	1 39 6	+ 11.1	0.44	− 4.4	*b*

Next is shown the comparison of the tabular and observed times. In the column "Phenomenon observed", S. signifies that the time of observation is that at which the eclipse was said to be sensible to the sight, whereas, in other cases, only the phrase beginning or ending is used. As these phenomena necessarily occur after the times of geometric first contact, they must be a little too late. The observed times of ending must be supposed too early by a less amount. In the table, however, the comparisons are made with the geometric contacts only. Column Δt shows the difference between the observed time and the computed tabular time of the geometric phase. It is next necessary to multiply this difference by the appropriate factor to reduce it to correction of the moon's mean longitude. For the required factor has been taken

$$\frac{dD}{dt} \div \frac{dD}{d\varepsilon};$$

these quantities being computed by the formulæ given in the next section, on the reduction of eclipses and occultations. In the case of eclipses of the moon, the factor may be supposed to have the constant value 0.51. Column Δl gives the individual corrections to the moon's mean longitude thus obtained.

In the last column, an attempt is made to classify the results. The letter *a* generally signifies that the materials for the determination of time are unexceptionable; *b*, that there is room for error, owing to the vertical circle drawn through the object of which the altitude was observed for time being too near the meridian, or to the eclipse being a small one; *c*, that the data for time are yet more defective, or that the time determined by the observers had to be used.

Passing now to the consideration of the results, we remark that these observations are not of the class in which a system of weights determined *a priori* can be adhered to, owing to the liability of the observations to abnormal errors. With a view of forming a judgment how far the observations are thus affected, we begin by finding the narrowest limits within which a majority of the results can be included, making no distinction of weights, and including all discordant observations. We readily find these limits of Δl to be $-0'.8$ and $-6'.8$, between which are included 17 out of the 33 results. This, taken alone, would indicate a mean correction of $-3'.8$, and a probable error of $3'$ for each observation. Extending the limits still farther, we find that 27 out of the 33 are contained on or between the limits $+2'.3$ and $-10'.6$, or, omitting the two contained on these limits, three fourths of the whole number of results are contained between them, while the outlying results are equal in number on each side. This would indicate an individual probable error of $3'.8$, with nearly the same mean result.

Reversing the reasoning, if we suppose a probable error of $3'$, then three fourths of the whole number of observations, or 25 in all, ought to be contained between limits extending through $10'.2$, while 27 should be contained between limits differing by $12'$, and the remaining 6 should lie but little outside the limits, always supposing the admitted law of error to hold. Most of the six outlying observations are so far from fulfilling this condition as to show conclusively that the law in question does not hold, and, therefore, that *the arithmetical mean is not the most probable final result.*

The following results are so far outside the limits of probable error as to be suspicious, if not certainly abnormal:—

829, November 29.—*Beginning.*—The tables show that the eclipse began at or before sunrise. How a real beginning could have been observed more than half an hour afterward, it is hard to see. The observation is, therefore, clearly inadmissible.

927, September 13.—Though the time from the altitude of Sirius is of the second order of accuracy, the observation with the astrolabe confirms it, so that the discrepancy is hard to account for. Possibly, the keen eye of the young observer caught the penumbra some time before the actual advent of the shadow. The smallness of the eclipse would only admit of giving half weight to the observation, even were the result good.

929, January 27.—Nothing can be done with this eclipse, the observed time appearing exceptionably free from a liability to possible error.

990, April 12.—Here we have nothing to check the record that the moon was 38° high "au moment de l'attouchement". I think the result should be rejected, especially as the term translated *attouchement* seems to be of doubtful meaning.

Of the four discordant eclipses, there will, I conceive, be no question that those of 829, 929, and 990 should be rejected. Respecting that of 927, doubt may be entertained; I, therefore, retain it. In taking the mean, it may seem advisable to give classes b and c half weight, compared with a.

We have, before taking any means, to consider the cases of those eclipses of which the phases of beginning are distinctly stated to be those when the eclipse was apparent to the view, which are marked (S.) in the third column. It might seem that all the observed beginnings should be referred to this phase, but the general run of the comparisons seems to favor the belief that the times were made to refer to the actual contacts by an estimate of the observer in each case. The correction to be applied for the phase in question does not admit of a definite determination, but must rest upon our estimate of the acuteness of the Arab vision. I conceive that we may assume $2\frac{1}{2}'$, a probable mean correction to reduce to geometrical contact; but what we really want to do is, not to reduce to real contact, but to the greatest phase of invisibility, so that the times of beginnings shall correspond to those of the endings when the eclipse was no longer visible. We shall, therefore, apply a correction of plus $1'.5$ to each value of $\varDelta l$ dependent on a phase of beginning marked (S.). The observations are clearly divisible into three groups, separated by pretty wide intervals. The mean results are:—

850	$\varDelta l = -3'.8 \pm 2'.4$	3 phases.
927	$-1'.6 \pm 1'.7$	7 phases.
986	$-4'.5 \pm 1'.3$	20 phases.

The probable errors are obtained on the supposition that the probable error of a result of class b is $\pm 4'.5$, and that each group is affected with a probable systematic error of $\pm 1'$ in addition to all accidental errors.

§ 6.

MODE OF DEDUCING THE ERRORS OF THE LUNAR ELEMENTS FROM THE ECLIPSES AND OCCULTATIONS.

The method of computing eclipses and occultations may generally be divided, though not perhaps with entire sharpness, into two classes: in the one, the position of the observer relatively to the cone, or cylinder, which circumscribes the moon and the occulted object is computed by geometric methods, and the condition of an occultation or of the beginning or end of an eclipse is that the observer shall be on the surface of this cone; in the second class, the apparent position and magnitude of the two bodies, as seen by the observer, are computed, and the corresponding condition is, that the apparent distance of centres shall be equal to the sum of the apparent semi-diameters. The first method is preferable on the score of elegance of treatment and of general certainty and convenience in cases where the phenomenon has been observed from several stations. It requires, however, that the positions of both bodies be known before the computations of the phenomenon are commenced. This requirement has prevented its use in the present investigation, because it was desirable to postpone the final determination of the positions of the stars to the latest practicable moment, in order that the best available data might be used. The method adopted is, therefore, to determine separately and independently the apparent positions of the moon and of the sun or star, and then to deduce equations of condition from the difference between the computed distance of centres and the sum of the semi-diameters; or, in the case of solar eclipses, from the difference between the observed and computed phases.

In this computation, I have used celestial longitudes and latitudes throughout, and not right ascensions and declinations. While there is, perhaps, no difference in the amount of labor involved in the two methods, the method adopted is recommended by the greater simplicity and directness of the computations, the ease with which they can be controlled. and the slightness of the modification which will be necessary if the results desired are only approximate. These advantages are especially seen in the computation of the apparent place of the star, which is so much more simple when the longitude and latitude are required than in the case of the right ascension and declination, that when two or three places are required for distant epochs, the labor of transforming the co-ordinates of the star may be fully compensated by the consequent ease with which its apparent place can be determined.

The investigation of the formulæ actually used is as follows:—

1.—*Apparent Place of the Moon.*

Put

r, l, b, the geocentric radius-vector, longitude, and latitude of the moon;

ρ, λ, β, the corresponding co-ordinates of the observer;

r', l', b', the corresponding co-ordinates of the moon as seen by the observer;

π, the moon's equatorial horizontal parallax; and

$$R = \frac{r'}{r}.$$

The values of λ and β are obtained from the observer's geocentric longitude and local sidereal time by changing the right ascension and declination of his geocentric zenith into longitude and latitude. If we take the earth's equatorial radius for unity of distance, the value of ρ may be taken at once from geodetic tables, or computed from well-known formulæ. Putting

φ', the observer's geocentric latitude;
τ, his sidereal time expressed in arc;
ω, the obliquity of the ecliptic,

compute u and k' from the formulæ

$$k' \sin u = \rho \sin \varphi';$$
$$k' \cos u = \rho \cos \varphi' \sin \tau.$$

Then, $\rho \cos \beta$, $\rho \sin \beta$, and λ are given by

$$\rho \cos \beta \cos \lambda = \rho \cos \varphi' \cos \tau;$$
$$\rho \cos \beta \sin \lambda = k' \cos (u - \omega) = \cos \omega \, \rho \cos \varphi' \sin \tau + \sin \omega \, \rho \sin \varphi';$$
$$\rho \sin \beta = k' \sin (u - \omega) = \cos \omega \, \rho \sin \varphi' - \sin \omega \, \rho \cos \varphi' \sin \tau.$$

A partial check on the accuracy of the computations may be obtained by computing $\sin \beta$ and $\cos \beta$, and noting that the two correspond to the same angle; but, as this quantity is not needed separate from ρ, I have preferred to depend on duplicate computation by different computers. It may be remarked that 5-place logarithms are always ample in this computation, and that the error from neglecting the nutation of the obliquity of the ecliptic can never exceed $0''.15$ in the apparent place of the moon.

Taking the earth's equatorial radius as unity, which gives

$$r \sin \pi = 1,$$

we have the three equations:—

$$\begin{aligned} R \cos b' \cos l' &= \cos b \cos l - \rho \cos \beta \sin \pi \cos \lambda. \\ R \cos b' \sin l' &= \cos b \sin l - \rho \cos \beta \sin \pi \sin \lambda. \\ R \sin b' &= \sin b - \rho \sin \beta \sin \pi. \end{aligned} \qquad (1)$$

Let α be any arbitrary angle. If we transform the first two equations into the two others,

$$(1) \times \cos \alpha + (2) \times \sin \alpha,$$
$$-(1) \times \sin \alpha + (2) \times \cos \alpha,$$

they will be:—

$$R \cos b' \cos (l' - \alpha) = \cos b \cos (l - \alpha) - \rho \cos \beta \sin \pi \cos (\lambda - \alpha).$$
$$R \cos b' \sin (l' - \alpha) = \cos b \sin (l - \alpha) - \rho \cos \beta \sin \pi \sin (\lambda - \alpha).$$

If we suppose $\alpha = \lambda$, they will be:—

$$\begin{aligned} R \cos b' \cos (l' - \lambda) &= \cos b \cos (l - \lambda) - \rho \cos \beta \sin \pi. \\ R \cos b' \sin (l' - \lambda) &= \cos b \sin (l - \lambda). \end{aligned} \qquad (2)$$

Apart from the number of decimals required, these equations are the most simple. They give $R \cos b'$ and $l' - \lambda$, while the third of equations (1) gives $R \sin b'$, whence b' and R are obtained. They require, however, the full number of decimals requisite

to determine a large angle with the required degree of accuracy. Since λ may be known only to 0′.1, while $l - \lambda$ must be known to 0″.1, it is necessary to see that the same value is subtracted from l, and then added to $l' - \lambda$.

If we suppose $\alpha = l$, the equations will be:—

$$\begin{aligned} R \cos b' \cos (l' - l) &= \cos b - \rho \cos \beta \sin \pi \cos (l - \lambda). \\ R \cos b' \sin (l' - l) &= \rho \cos \beta \sin \pi \sin (l - \lambda). \end{aligned} \quad (3)$$

These equations have the advantage of requiring only 6-place logarithms.

Having thus obtained R, b', $l' - l$ or $l' - \lambda$, and thence l', the apparent semidiameter of the moon, or s', is found from the equation

$$\sin s' = \frac{k \sin \pi}{R};$$

k being the ratio of the diameter of the moon to that of the earth. The semidiameter, s', is so minute that we may suppose it equal to its sine, making the equation for its determination, in seconds,

$$s' = \frac{[5.31443]\, k \sin \pi_{\iota}}{R}.$$

The value of k which we shall adopt is that of Oudemans,* 0.27264. This will give:—

$$\log k = 9.43559.$$

$$s' = \frac{[4.75002] \sin \pi}{R}.$$

2.—*Apparent Place of the Sun or Star.*

If the phenomenon is an eclipse of the sun, the position of the sun is derived immediately from the tables. It must, however, be corrected for parallax. Owing to the minuteness of this correction, and the near approach of the centres of the sun and moon during any phase of an eclipse, it will be sufficient to subtract the horizontal parallax of the sun from that of the moon, to use this difference instead of π in the preceding formulæ, and then to apply no correction to the place of the sun on account of parallax.

In the case of a star, the longitude and latitude are to be reduced to the date of the observation by applying precession, proper motion, nutation, and aberration. If we put

$\varkappa$, the rate of motion of the pole of the ecliptic on the celestial sphere;
γ, the longitude of the point toward which it is moving;
T, centuries after 1800; and
T', centuries after 1850,

the resulting rate of change of the longitude and latitude of a star arising from the motion of the ecliptic alone will be:—

In longitude, $\varkappa \tan B \sin (L - \gamma)$.
In latitude, $\varkappa \cos (L - \gamma)$.

These expressions being independent of the equinox of reference, we may, in them, suppose both L and γ to be referred to a fixed equinox.

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In reducing the star-places to the ecliptic, HANSEN'S obliquity will be used, the value of which is:—

$$\omega = 23^\circ\ 27'\ 54''.80 - 46''.78\ T.$$

Adopting this change of obliquity, as I have done in my *Investigation of the Orbit of Uranus*, where the motion of the pole of the ecliptic in the direction of the vernal equinox of 1850 is $5''.43\ T' + 0''.19\ T'^2$, and that in the direction of 90° greater longitude is $46''.78\ T' - 0''.06\ T'^2$, we find, taking the century as the unit of time, and counting from 1800,

$$\varkappa = 47''.09 - 0''.09\ T',$$
$$\gamma = 83^\circ\ 23' - 28'\ T';$$

γ being here counted from the fixed equinox of 1850. Counting from the equinox of 1800, the expression will be:—

$$\gamma = 82^\circ\ 55' - 28'\ T.$$

Taking the expressions just given for the motion in longitude and latitude, when the equinox is fixed, namely,

$$\frac{dL}{dT} = \varkappa \tan B \sin (L - \gamma),$$
$$\frac{dB}{dT} = \varkappa \cos (L - \gamma),$$

we find, by differentiating and substituting the numerical values of the centennial variations of $\varkappa$ and γ,

$$\frac{d^2L}{dT^2} = \tfrac{1}{2}\,\varkappa^2 \sec^2 B \sin 2\,(L - \gamma) - 0''.09 \tan B \sin (L - \gamma) + 28'\ \varkappa \tan B \cos (L - \gamma).$$

In the case of occulted stars, the maximum value of this expression is about $0''.04$, and the corresponding effect on the longitude of the star is $0''.02\ T^2$; it may, therefore, be entirely neglected. For the secular variation of the motion in latitude, we have, neglecting insensible terms,

$$\begin{aligned}\frac{d^2B}{dT^2} &= -\,0''.09 \cos (L - \gamma) - 28'\ \varkappa \sin (L - \gamma)\\ &= -\,0''.09 \cos (L - \gamma) - 0''.38 \sin (L - \gamma)\\ &= \quad 0''.39 \sin (L - \gamma + 194^\circ).\end{aligned}$$

The proper motion in longitude and latitude may be derived from those in right ascension and declination by the well-known formulæ for converting changes of the one system of co-ordinates into those of the other. If we put

μ, μ', μ_1, μ_2 the proper motions in right ascension, declination, longitude, and latitude respectively; and

E, the complement of the angle at the star of the triangle formed by the star and the poles of the equater and ecliptic,

we shall have:—

$$\cos E = \sin \omega \cos \alpha \sec B = \sin \omega \cos L \sec \delta.$$
$$\mu_1 = \mu \sin E \cos \delta \sec B + \mu' \cos E \sec B. \qquad (4)$$
$$\mu_2 = -\,\mu \cos E \cos \delta + \mu' \sin E.$$

Owing to the extreme slowness with which the position of the ecliptic changes, μ_1 and μ_2 may be supposed constant, which is not the case with μ and μ'.

Collecting the various terms in the motion of the star which we have deduced, and including precession, we find that its longitude and latitude, at the epoch T centuries after 1800, referred to the equinox of the epoch, is:—

$$\begin{aligned} L &= L_0 + L' T + L'' T^2; \\ B &= B_0 + B' T + B'' T^2; \end{aligned} \tag{5}$$

where we put

L_0, B_0, the longitude and latitude for 1800.0;

$$\begin{aligned} \gamma_0 &= 82^\circ\ 55'; \\ L' &= \mu_1 + 5024''.11 + 47''.14 \tan B_0 \sin (L_0 - \gamma_0); \\ L'' &= 1''.13; \\ B' &= \mu_2 + 47''.14 \cos (L_0 - \gamma_0); \\ B'' &= 0''.20 \sin (L_0 - \gamma_0 + 194^\circ). \end{aligned} \tag{6}$$

If we count L_0, B_0, and γ_0 from the equinox and ecliptic of 1850, and T from the epoch 1850.0, the same expressions will hold by putting

$$\begin{aligned} \gamma_0 &= 83^\circ\ 23'; \\ L' &= \mu_1 + 5025''.24 + 47''.09 \tan B_0 \sin (L_0 - \gamma_0); \\ L'' &= 1.13; \\ B' &= \mu_2 + 47''.09 \cos (L_0 - \gamma_0); \\ B'' &= 0''.20 \sin (L_0 - \gamma_0 + 194^\circ) = 0''.20 \sin (L_0 - 111^\circ). \end{aligned} \tag{6'}$$

Having thus obtained the mean position of the star for the required epoch, the apparent position is obtained by applying nutation and aberration. But, if the former correction be omitted from the place of the moon, it may be omitted from that of the star also. This course has been adopted. The correction for aberration is:—

$$\begin{aligned} \delta L &= -20''.45 \sec B \cos (\odot - L); \\ \delta B &= -20''.45 \sin B \sin (\odot - L); \end{aligned}$$

the symbol $\odot$ representing the sun's true longitude.

3.—*Distance of Centres of the Two Bodies.*

Having found, by the preceding methods,

L, B, the longitude and latitude of the star or sun,

l', b', s', the longitude, latitude, and semi-diameter of the moon,

the distance of centres, D, and the angle of position, m, of the line joining the centres are given by the equations:—

$$\begin{aligned} \sin \tfrac{1}{2} D \sin m &= \sin \tfrac{1}{2} (l' - L) \sqrt{\cos b' \cos B}; \\ \sin \tfrac{1}{2} D \cos m &= \sin \tfrac{1}{2} (b' - B); \end{aligned}$$

the angle m being counted from the south point of the moon's disk toward the west. We have also

$$\cos b' \cos B = \cos^2 \tfrac{1}{2} (b' + B) - \sin^2 \tfrac{1}{2} (b' - B).$$

Since the last term of this equation can never amount to $\frac{1}{10000}$, we may substitute $\cos\frac{1}{2}(b'+B)$ for $\sqrt{\cos b'\cos B}$ in the first of equations (6). We may also determine D and m with all necessary accuracy from the approximate equations,

$$D\sin m=(l'-L)\cos\tfrac{1}{2}(b'+B),$$
$$D\cos m=b'-B. \qquad (7)$$

The error in this determination of m will be of no importance, because this angle is never observed with such accuracy as to be used as a datum for correcting the moon's place, while the error in D is so small as to be entirely unimportant. In fact, if we represent by D' the approximate value of D derived from (7), we have:—

$$D'^2=(l'-L)^2\cos^2\tfrac{1}{2}(b'+B)+(b'-B)^2;$$

while developing the sines of $\frac{1}{2}D$, $\frac{1}{2}(l'-L)$, and $\frac{1}{2}(b'-B)$ in the rigorous equation to quantities of the third order, we have:—

$$\sin\tfrac{1}{2}D=\tfrac{1}{2}D\left(1-\frac{1}{24}D^2\right).$$
$$\sin\tfrac{1}{2}(l'-L)=\tfrac{1}{2}(l'-L)\left(1-\frac{1}{24}(l'-L)^2\right).$$
$$\sin\tfrac{1}{2}(b'-B)=\tfrac{1}{2}(b'-B)\left(1-\frac{1}{24}(b'-B)^2\right).$$

Substituting these values in the rigorous equations, and taking the sum of the squares of the two equations, we find

$$D^2=(l'-L)^2\cos^2\tfrac{1}{2}(b'+B)+(b'-B)^2+\frac{1}{12}\left(D^4-\varDelta l^4\cos^2\tfrac{1}{2}(b'+B)-\varDelta b^4\right),$$

where we have put, for brevity,

$$\varDelta l=l'-L;$$
$$\varDelta b=b'-B.$$

Substituting the above value of D'^2, we have

$$(D-D')(D+D')=\frac{1}{12}\left(D^4-\varDelta l^4\cos^2\tfrac{1}{2}(b'+B)-\varDelta b^4\right),$$

showing that the maximum value of $D-D'$ is $\frac{1}{48}D^3$, or less than $0''.01$. The equations (7) are therefore exact enough for all practical purposes.

4.—*Equations of Correction.*

If all the elements of reduction were correct, we should have, in case of an occultation, the value of D from (7) equal to that of s' from (4). We have now to find the equation of condition which must subsist among the corrections to the lunar elements in order that we may have $D=s'$. Owing to the minuteness of these corrections, their coefficients need not be accurate to more than two significant figures; we may therefore suppose $\cos\frac{1}{2}(b'+B)$ to be equal to unity, since its minimum value exceeds 0.995. If then we put, for brevity,

$$x=(l'-L)\cos\tfrac{1}{2}(b'+B),$$
$$y=b'-B,$$

$\frac{1}{2}(b'+B)$ differs so little from b that we may put

$$\delta x=(\delta l'-\delta L)\cos b,$$
$$\delta y=\delta b'-\delta B;$$

from which

$$\delta D = (\delta l' - \delta L) \cos b \sin m + (\delta b' - \delta B) \cos m. \qquad (8)$$

Let us now refer to the equations (1) and (3). If we put, for brevity,

$$\begin{aligned} p &= \rho \cdot \cos \beta \sin \pi, \\ q &= \rho \sin \beta \sin \pi, \end{aligned} \qquad (9)$$

we have from (3) and (1)

$$\tan (l' - l) = \frac{p \sin (l - \lambda)}{\cos b - p \cos (l - \lambda)},$$
$$R \sin b' = \sin b - q.$$

The angle $l' - l$, or the parallax in longitude, is so small that we may suppose it equal to its tangent, while the denominator, $\cos b - p \cos (l - \lambda)$, is always contained between the limits 0.98 and unity. Again, the quantity R is always contained between the limits 0.982 and unity. We may then put, without an error of more than one hundredth in the coefficients,

$$\begin{aligned} l' - l &= 1.01\, p \sin (l - \lambda), \\ \sin b' &= \frac{1}{R} (\sin b - q). \end{aligned} \qquad (10)$$

From these equations we obtain

$$\delta l' = \{1 + 1.01\, p \cos (l - \lambda)\}\, \delta l + 1.01 \sin (l - \lambda)\, \delta p - 1.01\, p \cos (l - \lambda)\, \delta \lambda;$$

and, putting $\cos b$ and $\cos b'$ equal to unity,

$$\delta b' = 1.01\, \delta b - 1.01 \delta q - \frac{1}{R^2} (\sin b - q)\, \delta R. \qquad (11)$$

Owing to the minuteness of p, q, δb, δp, and δq, the factor 1.01 may be entirely omitted in the above expressions. We have next, from (9), putting $\cos \pi$ equal to unity:—

$$\begin{aligned} \delta p &= \rho \cos \beta\, \delta \pi - q\, \delta \beta. \\ \delta q &= \rho \sin \beta\, \delta \pi + p\, \delta \beta. \end{aligned}$$

The longitude and latitude of the observer's geocentric zenith, λ and β, are functions of his latitude and of the local sidereal time. The former must be supposed to be known; but the variation of the latter may be taken into account in order to determine the effect of an error in the time of observation upon the lunar elements. The most simple formulæ for expressing errors of longitude and latitude in terms of the errors of right ascension and declination are those of Gauss, in his *Theoria Motus Corporum Coelestium*, § 68, and are these:—Determine the angle E between 0° and 180° from the equation

$$\cos E = \sin \omega \cos \tau \sec \beta = \sin \omega \cos \lambda \sec \varphi'.$$

Then

$$\begin{aligned} \delta \lambda &= \cos \varphi' \sin E \sec \beta\, \delta \tau + \cos E \sec \beta\, \delta \varphi', \\ \delta \beta &= - \cos \varphi' \cos E\, \delta \tau + \sin E\, \delta \varphi'. \end{aligned}$$

The last term in each equation is included only for the sake of completeness in writing. The substitution of this value in δp and δq, neglecting $\delta\varphi'$, gives:—

$$\delta p = \rho \cos \beta\, \delta\pi + q \cos \varphi' \cos E\, \delta\tau.$$
$$\delta q = \rho \sin \beta\, \delta\pi - p \cos \varphi' \cos E\, \delta\tau.$$

The correction to the tabular ecliptic longitude is represented by δl. For the sake of completeness, we shall suppose the local mean time of observation to require the correction δt, and the west longitude of the plane to require the correction $\delta\lambda'$. We shall then have, for the total correction to the moon's geocentric longitude and latitude,

$$\delta l + (\delta t + \delta\lambda')\frac{dl}{dt},$$
$$\delta b + (\delta t + \delta\lambda')\frac{db}{dt},$$

which are to be substituted for δl and δb in (11).

By taking the square root of the sum of the squares of equations (1), neglecting terms of the second order with respect to the parallax, we find:—

$$R = 1 - p \cos b \cos (l - \lambda) - q \sin b.$$

Hence

$$\delta R = - \cos b \cos (l - \lambda)\, \delta p - \sin b\, \delta q + p \cos b \sin (l - \lambda)(\delta l - \delta\lambda)$$
$$+ (p \sin b \cos (l - \lambda) - q \cos b)\, \delta b;$$

or, by substituting for δp, δq, and $\delta\lambda$ their values,

$$\begin{aligned}\delta R = {} & p \cos b \sin (l - \lambda)\, \delta l + (p \sin b \cos (l - \lambda) - q \cos b)\, \delta b \\ & + \rho \cos \varphi' \sin \pi \{\cos \beta \cos E \sin b - \sin E \cos b \sin (l - \lambda) \\ & - \sin \beta \cos E \cos b \cos (l - \lambda)\}\, \delta\tau - \rho (\cos \beta \cos b \cos (l - \lambda) + \sin \beta \sin b)\, \delta\pi\end{aligned}$$

In these several equations, τ is the sidereal time expressed in arc; and, by taking for the unit of time that in which the earth rotates through unity of arc, we may suppose $\delta t = \delta\tau$. If we substitute these several expressions in (11), omitting the factor .01, which renders the terms in which it occurs unimportant, omitting also the terms which contain $\sin b \sin \pi$ or $\sin^2 b$ as a factor, we find:—

$$\begin{aligned}\delta l' = {} & \{1 + p \cos (l - \lambda)\}\, \delta l + \{1 + p \cos (l - \lambda)\}\frac{dl}{dt}\, \delta\lambda' \\ & + \{[1 + p \cos (l - \lambda)]\frac{dl}{dt} + \rho \cos \varphi' \sin \pi\, [\sin \beta \cos E \sin (l - \lambda) \\ & - \sin E \cos (l - \lambda)]\}\, \delta\tau + \rho \cos \beta \sin (l - \lambda)\, \delta\pi. \qquad (12)\end{aligned}$$

$$\begin{aligned}\delta b' = {} & \delta b + \frac{db}{dt}\, \delta\lambda' + \left(\frac{db}{dt} + p \cos \varphi' \cos E\right) \delta\tau \\ & + \{\sin b \cos \beta \cos b \cos (l - \lambda) - \sin \beta\}\, \rho\, \delta\pi.\end{aligned}$$

The coefficients of $\delta\pi$ in these equations may be obtained with greater ease, and with ample accuracy, from the expressions:—

$$\frac{dl'}{d\pi} = \frac{l' - l}{\pi}.$$

$$\frac{db'}{d\pi} = \frac{b' - b}{\pi}.$$

Our next step will be to substitute the corrections of the moon's longitude in orbit and of the position of the plane of the orbit for those of the ecliptic longitude and latitude. Let us put

v, the moon's longitude in orbit, counted from a departure point in the orbit;
θ, the longitude of the node;
ϖ, the longitude of the perigee;
i, the inclination of the orbit;
u, the argument of latitude; and
β', a latitude counted in a direction perpendicular to the plane of the orbit:

the ecliptic longitude and latitude will then be given in terms of u, θ, and i, by the equations

$$\tan(l - \theta) = \cos i \tan u,$$
$$\sin b = \sin i \sin u;$$

whence we derive, for the differential variations,

$$\cos b\ \delta l = \cos b\ \delta\theta + \sec b \cos i\ \delta u - \sin b \cos(l - \theta)\ \delta i,$$
$$\cos b\ \delta b = \sin i \cos u\ \delta u + \cos i \sin u\ \delta i.$$

As we have defined v and β', their variations are given by the equations

$$\begin{aligned} \delta v &= \delta u + \cos i\ \delta\theta, \\ \delta\beta' &= \sin u\ \delta i - \sin i \cos u\ \delta\theta. \end{aligned} \tag{13}$$

The relation of these four equations is such that $\cos b\ \delta l$ and δb admit of being expressed as functions of δv and $\delta\beta'$ simply. The equations for this purpose are:—

$$\begin{aligned} \cos b\ \delta l &= \frac{\cos i}{\cos b}\ \delta v - \sin i \cos(l - \theta)\ \delta\beta'. \\ \delta b &= \sin i \cos(l - \theta)\ \delta v + \frac{\cos i}{\cos b}\ \delta\beta'. \end{aligned} \tag{14}$$

In fact, by substituting in these equations the values of δv and $\delta v'$ from (13), we shall reproduce the expressions for $\cos b\ \delta l$ and $\cos b\ \delta b$ just given.

If we determine an angle α by the equation

$$\sin \alpha = \sin i \cos(l - \theta),$$

we shall have

$$\frac{\cos i}{\cos b} = \cos \alpha;$$

and α will then be the angle which the moon's orbit makes with the parallel of latitude.

If in (12) we put, for brevity,

$$1 + p \cos (l - \lambda) = f,$$

the quantity f will be so near unity that we may suppose δb to be multiplied by it without any sensible error. Taking, next, so much of the expression for δD in (8) as depends on the place of the moon, namely,

$$\delta D = \cos b \ \delta l' \sin m + \delta b' \cos m,$$

if we substitute for δl and $\delta b'$ the terms of (12) which depend on δl and δb, we find

$$\delta D = f (\sin m \cos b \ \delta l + \cos m \ \delta b);$$

while substituting the angle α, (14) become

$$\cos b \ \delta l = \cos \alpha \ \delta v - \sin \alpha \ \delta \beta',$$
$$\delta b = \sin \alpha \ \delta v + \cos \alpha \ \delta \beta';$$

whence we derive

$$\delta D = f \{ \sin (m + \alpha) \ \delta v + \cos (m + \alpha) \ \delta \beta' \}. \qquad (15)$$

If we substitute for δv and $\delta \beta'$ their values in (13), we shall have

$$\delta D = f \{ \sin (m + \alpha) \ \delta u + \cos (m + \alpha) \sin u \ \delta i$$
$$+ [\cos i \sin (m + \alpha) - \sin i \cos (m + \alpha) \cos u] \ \delta \theta \}.$$

Representing the moon's mean longitude counted in the usual way by ε, we shall have

$$v = \varepsilon + Q;$$

Q representing the equation of the centre and the other inequalities, and being a function of ε, ϖ, and θ, and of the sun's mean longitude, which we represent by ε'. We then have:—

$$\frac{dv}{dt} = n \left(1 + \frac{dQ}{d\varepsilon} \right) + n' \frac{dQ}{d\varepsilon'} + \frac{dQ}{d\varpi} \cdot \frac{d\varpi}{dt} + \frac{dQ}{d\theta} \cdot \frac{d\theta}{dt}.$$
$$\delta v = \left(1 + \frac{dQ}{d\varepsilon} \right) \delta \varepsilon + \frac{dQ}{d\varpi} \ \delta \varpi + \frac{dQ}{d\theta} \ \delta \theta. \qquad (16)$$

Owing to the minuteness of the terms of E which contain ε', as well as of $\frac{d\varpi}{dt}$ and $\frac{d\theta}{dt}$, we may put

$$\frac{dv}{d\varepsilon} = 1 + \frac{dQ}{d\varepsilon} = \frac{1}{n} \cdot \frac{dv}{dt},$$

without an error of more than $\frac{1}{500}$ of the whole expression. We have also, with sufficient accuracy,

$$\frac{dQ}{d\varpi} = -2 e \cos g;$$

g being the moon's mean anomaly. The coefficient $\frac{dQ}{d\theta}$ may be omitted entirely. Sub-

stituting in (15) the value of $\delta\beta'$ from (13), and that of δv from (16), after making the substitutions just indicated, we find

$$\delta D = f \Big\{ \sin(m+\alpha)\frac{1}{n}\cdot\frac{dv}{dt}\delta\varepsilon - 2\sin(m+\alpha)\cos g\ e\ \delta\varpi + \cos(m+\alpha)\sin u\ \delta i$$
$$- \cos(m+\alpha)\cos u \sin i\ \delta\theta \Big\}.$$

In the use of this formula, $\frac{dl}{dt}$ may be substituted for $\frac{dv}{dt}$, owing to the comparative minuteness of the difference between the two expressions.

Next, to find the value of $\frac{dD}{d\tau}$ or $\frac{dD}{dt}$, we substitute the proper terms of (12) in (8). From the latter we have

$$\frac{dD}{dt} = \sin m \cos b \left(\frac{dl'}{dt} - \frac{dL}{dt}\right) + \cos m\frac{db'}{dt};$$

and from the former, omitting the factor $f = 1 + p\cos(l-\lambda)$,

$$\frac{dl'}{dt} = \frac{dl}{dt} + \rho\cos\varphi'\sin\pi\ \{\sin\beta\cos E\sin(l-\lambda) - \sin E\cos(l-\lambda)\},$$
$$\frac{db'}{dt} = \frac{db}{dt} + p\cos\varphi'\cos E.$$

For the terms of $\frac{dD}{dt}$, independent of the moon's parallax, we find, with sufficient approximation,

$$\frac{dv}{dt}\sin(m+\alpha), \qquad \text{or} \qquad \frac{dl}{dt}\sin(m+\alpha).$$

For the other terms, we determine the quantities h and ψ by the equations

$$\cos h = \cos\beta\cos E = \sin\omega\cos\tau;$$
$$\sin h\sin(\psi-\lambda) = \sin E;$$
$$\sin h\cos(\psi-\lambda) = \sin\beta\cos E.$$

The angle h is to be taken between $0°$ and $180°$, so that $\sin h$, like $\sin E$, is always positive. With this restriction, $\psi-\lambda$ may be obtained from the formula

$$\tan(\psi-\lambda) = \frac{\tan E}{\sin\beta}.$$

The angle $\psi-\lambda$ must therefore be included between the same limits. If we omit the factor $\cos b$, the terms which depend upon the parallax now become:—

$$\rho\cos\psi'\sin\pi\ (\sin h\sin m\sin(l-\psi) + \cos h\cos m).$$

The entire expression for $\frac{dD}{dt}$ now becomes

$$\frac{dD}{dt} = \frac{dl}{dt}\sin(m+\alpha) + \rho\cos\varphi'\sin\pi\ (\sin h\sin m\sin(l-\psi) + \cos h\cos m) - \frac{dL}{dt}\sin m.$$

h, being a function of τ simply, and independent of the place of observation, may be tabulated with τ as the argument.

For the coefficients depending on the longitude of the place, we have

$$\frac{dD}{d\lambda'} = f\frac{dl}{dt}\sin m + \frac{db}{dt}\cos m,$$

for which we may put

$$\frac{dD}{d\lambda'} = f\frac{dv}{dt}\sin(m+\alpha).$$

For the coefficient in respect to the parallax, we have

$$\frac{dD}{d\pi} = \frac{l'-l}{\pi}\sin m + \frac{b'-b}{\pi}\cos m.$$

In those of the preceding expressions which depend on the adopted unit of time, it will be remembered that this unit is tacitly supposed equal to the time in which the earth rotates through the radius unit of arc, or

$$\frac{24 \text{ sidereal hours}}{2\pi},$$

or,

$$\begin{aligned}&\text{In sidereal time, } 13751^{s} = 229^{m}.2 = 3^{h}.82;\\ &\text{In mean time, } 13713^{s} = 228^{m}.6 = 3^{h}.81.\end{aligned}$$

Numerical factors will be required when the second is taken as the unit of arc.

The formulæ to be actually employed in the computations may now be recapitulated as follows:—

(1) From the geocentric latitude of the place, φ', and the sidereal time at which an occultation was observed, τ, compute the ecliptic co-ordinates of the observer, λ, $\rho\sin\beta$, and $\rho\cos\beta$, by the formulæ:—

$$\begin{aligned}\rho\cos\beta\cos\lambda &= \rho\cos\varphi'\cos\tau,\\ \rho\cos\beta\sin\lambda &= k'\cos(u'-\omega),\\ \rho\sin\beta &= k'\sin(u'-\omega);\end{aligned}$$

the quantities k' and u' being first determined from the equations

$$\begin{aligned}k'\sin u' &= \rho\sin\varphi',\\ k'\cos u' &= \rho\cos\varphi'\sin\tau.\end{aligned}$$

Five-place logarithms are always sufficient for this computation.

(2) Put

$$\begin{aligned}p &= \rho\cos\beta\sin\pi,\\ q &= \rho\sin\beta\sin\pi;\end{aligned}$$

and compute R, l', b', and s' from the equations

$$\begin{aligned}R\cos b'\sin(l'-l) &= p\sin(l-\lambda),\\ R\cos b'\cos(l'-l) &= \cos b - p\cos(l-\lambda),\\ R\sin b' &= \sin b - q,\\ s' &= \frac{[4.75002]\sin\pi}{R};\end{aligned}$$

l, b, and π being the tabular geocentric longitude, latitude, and parallax of the moon for the moment of observation. Here 5-place logarithms are enough for terms having $\sin \pi$ as a factor. Elsewhere, 6 are required.

(3) Having found the apparent longitude and latitude, L and B, of the eclipsed sun or occulted star, find D and m from the equations

$$D \sin m = (l' - L) \cos \tfrac{1}{2} (b' + B),$$
$$D \cos m = b' - B,$$

using 5-place logarithms. In the computations of the differential coefficients which follow, 3 places are sufficient.

(4) Find the angles E, $\psi - \lambda$, and h, all between 0° and 180°, from the equations

$$\cos E = \sin \omega \sec \beta \cos \tau,$$
$$\cos h = \sin \omega \cos \tau,$$
$$\tan (\psi - \lambda) = \frac{\tan E}{\sin \beta}.$$

For any one place, these angles may all be tabulated as a function of τ; and the values of $\sin h$ and $\cos h$, being independent of the latitude, will answer for any place whatever.

(5) Find α from the equation

$$\alpha = 5^\circ.14 \sin u,$$

which may be tabulated as a function of u.

(6) Put (l') for the motion of the moon's geocentric longitude in $0^d.01$, expressed in minutes of arc. Then

$$\frac{dv}{d\varepsilon} = \frac{(l')}{7.90}.$$

(7) Find the moon's mean anomaly, g. When Hansen's tables are employed, the disturbed anomaly may be used, and found by the formula

$$g = 13^\circ.065 (z - 15.18).$$

(8) The several differential coefficients which admit of being determined from the eclipse or occultation are then as follows:—

$$\frac{dD}{d\varepsilon} = \frac{dv}{d\varepsilon} \sin (m + \alpha).$$

$$\frac{dD}{e\, d\varpi} = -2 \cos g \sin (m + \alpha).$$

$$\frac{dD}{i\, d\theta} = -\cos u \cos (m + \alpha).$$

$$\frac{dD}{di} = \sin u \cos (m + \alpha).$$

$$\frac{dD}{d\pi} = \frac{l' - l}{\pi} \sin m + \frac{b' - b}{\pi} \cos m.$$

$$\frac{dD}{d\beta'} = \cos(m + \alpha).$$

$$\frac{dD}{dt} = \frac{(l')}{14.4} \sin(m + \alpha)$$
$$+ 15.05\ \rho \cos \varphi' \sin \pi \{\sin h \sin m \sin (l - \psi) + \cos h \cos m\} - \frac{(L')}{14.4} \sin m.$$

$$\frac{dD}{d\lambda'} = \frac{(l')}{14.4} \sin(m + \alpha).$$

In case of an occultation, the equation of condition will be

$$\frac{dD}{d\varepsilon}\,\delta\varepsilon + \frac{dD}{e\,d\varpi}\,e\,\delta\varpi + \text{etc.} = s' - D.$$

A similar formula will hold for eclipses of the sun computed in this way, except that the distance of centres determined from the observed phase must be substituted for s'.

§ 7.

EFFECT OF CHANGES IN THE LUNAR ELEMENTS UPON THE PATH OF THE CENTRAL LINE OF AN ECLIPSE.

Not only in all ancient eclipses, but frequently in modern ones, the data derived from observation are not times, but the lines along which the edge or some point of the shadow passes. To utilize such observations, it is necessary to express the change in the central line due to changes in the moon's co-ordinates or elements. This I have done by Bessel's formulæ, in the very simple form in which they are developed by Professor Peirce in his *Trigonometry*. The notation is as follows:—

λ, the moon's geocentric longitude, *minus* that of the sun;
β, the moon's latitude, diminished by that of the sun, if necessary;
ε, the obliquity of the ecliptic;
u, the angle of position of the great circle drawn from the centre of the sun through that of the moon, measured toward the east from the circle drawn to the pole of the ecliptic;
ϖ, the angle which the same circle makes with the meridian passing through the sun;
π, the sun's equatorial horizontal parallax at the time;
Π, that of the moon;
γ, the angular geocentric distance of the centres of the two bodies;
m, the ratio of their linear distances from the earth's centre;
c, the angular distance of the centres of the earth and moon as seen from that of the sun;
α', δ', the right ascension and declination of the sun;
a, d, those of the line joining the centres of the sun and moon;
L, the sun's longitude.

We then have:—

$$\begin{aligned}
\tan\gamma \sin u &= \tan \lambda.\\
\tan\gamma \cos u &= \tan\beta \sec \lambda.\\
m &= \frac{\sin \pi}{\sin \Pi}.\\
c &= 206265'' \, m \tan\gamma \cos\gamma.\\
\tan(u-\omega) &= \cos L \tan \varepsilon.\\
d &= \delta' - c\cos\omega.\\
a &= \alpha' - c \sin\omega \sec\delta'.\\
\omega' &= \omega - c\sin\omega\tan\delta'.\\
R &= \frac{\sin(\gamma + c)}{\sin \Pi}.
\end{aligned} \tag{1}$$

The co-ordinates of the point in which the centre of the shadow intersects the plane perpendicular to it passing through the centre of the earth will be, when reckoned in the usual way:—

$$\begin{aligned}
x &= R\sin\omega'.\\
y &= R\cos\omega'.
\end{aligned} \tag{2}$$

Next, putting

φ', the geocentric latitude of a point on the earth's surface;
ρ, its distance from the earth's centre;
μ', the west hour-angle of the axis of the shadow counted from the meridian of the place; or,

$$\mu' = \text{sid. time} - a = \text{apparent time} + c\sin\omega\sec\delta';$$

the corresponding co-ordinates of the place are

$$\begin{aligned}
\xi &= \rho\cos\varphi'\sin\mu',\\
\eta &= \rho(\sin\varphi'\cos d - \cos\varphi\sin d\cos\mu'),\\
\zeta &= \rho(\sin\varphi'\sin d + \cos\varphi'\cos d\cos\mu');
\end{aligned} \tag{3}$$

and the hourly variations of the first two are

$$\begin{aligned}
\xi' &= [9.4192]\,\rho\cos\varphi'\cos\mu',\\
\eta' &= [9.4192]\,\rho\cos\varphi'\sin d\sin\mu'.
\end{aligned}$$

The distance of this place from the axis of the shadow at any time is

$$\sqrt{(x-\xi)^2 + (y-\eta)^2}.$$

The quantities x, ξ, y, and η, which enter into this equation, are functions of the time and of the elements of the lunar orbit. The datum supposed to be given by observation is the least distance of the place from the axis of the shadow, or the minimum value of the above expression. We are to express this minimum value in terms of the tabular elements and of the corrections to the moon's longitude and latitude and to the longitude of the sun. To compute the tabular minimum, we are supposed to be able to fix a time, τ, so near it that the differential coefficients of ξ, η, x, and y may be

regarded as constant during the interval between τ and the time of minimum distance. We, therefore, suppose that for a time, t, including the moment in question, we have:—

$$
\begin{aligned}
x &= x_0 + x' \, (t - \tau), \\
y &= y_0 + y' \, (t - \tau), \\
\xi &= \xi_0 + \xi' \, (t - \tau), \\
\eta &= \eta_0 + \eta' \, (t - \tau),
\end{aligned}
\tag{4}
$$

the subscript zeros indicating the tabular values at the time τ. Now, putting, for brevity,

$$
\begin{aligned}
X &= x_0 - \xi_0, \\
Y &= y_0 - \eta_0, \\
X' &= x' - \xi', \\
Y' &= y' - \eta',
\end{aligned}
\tag{5}
$$

the square of the distance of centres at the time t will be

$$X^2 + Y^2 + 2\,(XX' + YY')\,(t - \tau) + (X'^2 + Y'^2)\,(t - \tau)^2,$$

which will be at a minimum when

$$t - \tau = -\frac{XX' + YY'}{X'^2 + Y'^2}.$$

The minimum value of the square will be found by substituting this value of $t - \tau$ in the preceding equation, and is

$$\frac{(X'Y - XY')^2}{X'^2 + Y'^2},$$

so that the actual tabular value of the minimum distance is

$$\varDelta = \frac{X'Y - XY'}{\sqrt{X'^2 + Y'^2}}, \tag{6}$$

which is positive when the observer, facing in the direction in which the shadow is moving, sees the axis of the latter pass him on his left hand. As the shadow always moves toward the east, $\varDelta$ will be positive when the axis of the shadow passes north of the place.

The minimum distance being thus expressed as a function of tabular quantities at the time τ, the change of this distance due to a change in those quantities will express the corresponding change in the path of the centre of the shadow, which will be positive when the change is toward the north. The changes to be considered will be those which will be produced fundamentally by small changes in the latitude, longitude, and parallax of the moon, and the longitude of the sun. Omitting the subscript zeros from x and y, we find, from the equations already given,

$$
\begin{aligned}
\delta x &= \sin \omega' \; \delta R + R \cos \omega' \; \delta \omega', \\
\delta y &= \cos \omega' \; \delta R - R \sin \omega' \; \delta \omega'.
\end{aligned}
\tag{7}
$$

The quantity c is so minute that we may neglect both its changes and the terms in which it appears as a factor. Moreover, β, γ, and λ are all so small that we may

put their cosines equal to unity without any error changing the differential coefficients by their thousandth part.

The rigorous value of δR being

$$\delta R = \frac{\cos(\gamma + c)}{\sin \Pi}(\delta\gamma + \delta c) - \frac{\sin(\gamma + c)}{\sin^2 \Pi} \cos \Pi \, \delta \Pi,$$

a value correct to its four-hundredth part will be

$$\delta R = \frac{\delta\gamma}{\sin \Pi} - \frac{\gamma \, \delta \Pi}{\sin^2 \Pi}. \tag{8}$$

The approximate value of c is $\frac{\gamma}{400}$, the denominator being the ratio of the distances of the sun and moon; a farther approximation to the true value of δR will therefore, be obtained by increasing the right-hand side of the last equation by its four-hundredth part. We have, to a still greater degree of approximation,

$$\delta\omega' = \delta\omega;$$

and, by differentiating the expression for $(u - \omega)$,

$$\delta\omega - \delta u = \tan \varepsilon \cos^2 (u - \omega) \sin L \, \delta L. \tag{9}$$

The maximum value of this term is 0.4 δL. The probable error of the sun's tabular mean motion does not exceed $1''$ per century; the right-hand side of this equation can, therefore, scarcely ever amount to $10''$ during historic times. The greatest error in δx and δy which can arise from omitting it will therefore be of the order of magnitude

$$R \times 10'' \text{ or } \frac{R}{20000}.$$

The maximum value of R being about 4000 miles, the corresponding error in the path of the shadow will be less than 400 yards for the most ancient eclipses, and less than 50 yards for the modern ones. It may therefore be entirely omitted, which will make

$$\delta\omega = \delta u.$$

We have thus made the variations of x and y to depend on those of u, γ, and Π by the equations (7), (8), and (9). We have next to express the variations of u and γ in terms of the variations of the elements on which they depend. Since we suppose $\cos\gamma$, $\cos\lambda$, and $\cos\beta$ to be sensibly unity, we find, by differentiating the first two of equations (1),

$$\sin u \, \delta\gamma + \gamma \cos u \, \delta u = \delta\lambda,$$
$$\cos u \, \delta\gamma - \gamma \sin u \, \delta u = \delta\beta;$$

which give

$$\delta\gamma = \sin u \, \delta\lambda + \cos u \, \delta\beta,$$
$$\gamma \, \delta u = \cos u \, \delta\lambda - \sin u \, \delta\beta.$$

If we substitute in (7) for R is approximate value $\frac{\sin \gamma}{\sin \Pi}$ and for δR and $\delta \omega'$ the values derived from the equations (8) and (9), the expressions for δx and δy reduce to

$$\delta x = \frac{\cos (u - \omega')}{\sin \Pi} \delta \lambda - \frac{\sin (u - \omega')}{\sin \Pi} \delta \beta - \frac{\gamma \sin \omega'}{\sin^2 \Pi} \delta \Pi,$$
$$\delta y = \frac{\sin (u - \omega')}{\sin \Pi} \delta \lambda + \frac{\cos (u - \omega')}{\sin \Pi} \delta \beta - \frac{\gamma \cos \omega'}{\sin^2 \Pi} \delta \Pi. \qquad (10)$$

As already shown, if we put ω in place of ω', the error thus introduced will be, at its maximum only about $\frac{1}{400}$ of the total amount of the corrections, which will be quite unimportant in all cases. If we suppose the right ascension and declination as well as the longitude of the sun to be known, we have

$$\cos (u - \omega) = \frac{\sin \alpha'}{\sin L},$$
$$\sin (u - \omega) = \cot L \tan \delta',$$

which may be substituted in (10). But, as $u - \omega$ has necessarily to be computed, it may be more convenient to use the equations unchanged.

The expression (6) for Δ contains not only x and y, but their derivatives with respect to the time, which are multiplied by the interval $t - \tau$. Since we can choose the time τ as near as we please to the moment of passage of the shadow, we may make the effect of these terms as minute as we please; but, owing to the extreme slowness with which $u - \omega$ changes, the effect of $\delta \lambda$ and $\delta \beta$ on the derivatives of x and y will under all circumstances be insensible, while the minuteness of the correction to the parallax will render the derivative of the last term of δx and of δy inappreciable. We may therefore suppose

$$\delta \frac{dx}{dt} = \frac{d\ x}{dt} = 0,$$
$$\frac{dy}{dt} = \frac{d\delta y}{dt} = 0.$$

We have next to investigate the changes which may be produced in ξ and η by changes in the relative positions of the sun and moon. The change in d will be very nearly that in the sun's declination, which can scarcely exceed 20″ within historic times, and 2″ within the last two or three centuries. These changes would correspond respectively to 2000 feet and 200 feet on the earth's surface, and may therefore be neglected. The changes in ξ and η will therefore depend upon those of μ', or of the hour-angle of the line joining the centres of the sun and moon. If we represent by E the equation of time, and by t_1 the local mean time, the value of μ' is

$$t_1 - E + c \sin \omega \sec \delta;$$

or if, for the moment, we represent the west longitude of the point of observation by λ_1, the value for the assumed time will be

$$\mu' = \tau - \lambda_1 - E + c \sin \omega \sec \delta. \qquad (10)$$

Of these quantities, τ, the absolute time for which the computation is made, is arbitrarily assumed, and is not subject to correction, the actual time having been eliminated from the expression (6) for $\varDelta$; λ_1, the longitude of the place, is necessarily supposed to be known; the error of E cannot exceed a few seconds; its effect is therefore insensible; while c is so small and well determined that the changes in the last term of the expression are insensible. We may therefore consider ξ and η to be unaffected by any changes in the lunar and solar elements.

It appears, then, that to find the change in $\varDelta$ we need only change x and y. We therefore obtain from (6)

$$\delta\varDelta = \frac{X'\,\delta y - Y'\,\delta x}{\sqrt{X'^2 + Y'^2}},$$

or, for the differential coefficients, using equations (10) and putting ω for ω',

$$\sin\Pi\,\frac{d\varDelta}{d\lambda} = \sin\Pi\left(\frac{d\varDelta}{dx}\,\frac{dx}{d\lambda} + \frac{d\varDelta}{dy}\,\frac{dy}{d\lambda}\right)$$

$$= \frac{X'\sin(u-\omega) - Y'\cos(u-\omega)}{\sqrt{X'^2 + Y'^2}};$$

$$\sin\Pi\,\frac{d\varDelta}{d\beta} = \frac{X'\cos(u-\omega) + Y'\sin(u-\omega)}{\sqrt{X'^2 + Y'^2}};$$

$$\sin\Pi\,\frac{d\varDelta}{d\Pi} = \frac{\gamma}{\sin\Pi}\cdot\frac{Y'\sin\omega' - X'\cos\omega'}{\sqrt{X'^2 + Y'^2}}.$$

The most convenient formulæ for computation will be:—

$$\left.\begin{aligned}
\tan S &= \frac{Y'}{X'},\ (90^\circ > S > -90^\circ).\\
\frac{d\varDelta}{d\gamma} &= \frac{\sin(u-\omega-S)}{\sin\Pi}.\\
\frac{d\varDelta}{d\beta} &= \frac{\cos(u-\omega-S)}{\sin\Pi}.\\
\frac{d\varDelta}{d\Pi} &= -\frac{\gamma\cos(\omega-S)}{\sin^2\Pi}.
\end{aligned}\right\}\qquad (12)$$

In these expressions, the unit of $\varDelta$ is the earth's equatorial radius, and that of λ and β is the unit radius of arc. It will be remembered that $\varDelta$ is here the smallest perpendicular distance of the place from the centre of the shadow, and must not be confounded with the corresponding distance measured on the surface of the earth.

If nothing more is known of an eclipse than that it was total at a given place, $\varDelta$ may have any value less than the radius of the shadow. We cannot then form an absolute equation of condition, but can only assign two limits within which a certain linear function of the corrections $\delta\lambda$ and $\delta\beta$ must be contained. The following formulæ are sufficiently accurate for this purpose. Compute the angle of the cone of the shadow by the formula

$$\log\sin f = \frac{[7.66669]}{r'\,\{1 - m\cos(\gamma + c)\}};$$

f being the angle in question, and r' the distance or radius vector of the sun, its mean distance being unity as given in the ephemeris. The formula

$$\log \sin f = \frac{[7.6678]}{r'}$$

will answer for all practical purposes. Compute also the distance of the moon's centre from the fundamental plane,

$$z = \frac{\cos(\gamma + c)}{\sin \Pi};$$

and compute the value of ζ for the place from the third of formula (3). Then we have

$$\rho_1 = (z - \zeta) \tan f - 0.27227 \sec f; \qquad (13)$$

ρ_1 being the radius of the shadow. If now $\varDelta_0$ represent the tabular distance at which the axis of the shadow passes, as given by formula (6), the value of $\varDelta_0 + \delta\varDelta$ must be contained between the limits $+\rho_1$ and $-\rho_1$. The expression for this function is

$$\varDelta_0 + \frac{d\varDelta}{d\lambda}\delta\lambda + \frac{d\varDelta}{d\beta}\delta\beta + \frac{d\varDelta}{d\pi}\delta\pi.$$

The condition sought is therefore

$$\rho_1 - \varDelta_0 > \frac{d\varDelta}{d\lambda}\delta\lambda + \frac{d\varDelta}{d\beta}\delta\beta + \frac{d\varDelta}{d\pi}\delta\pi > -\rho_1 - \varDelta_0.$$

We have now to introduce, in place of λ and β, the mean longitudes of the sun and moon and the longitude of the moon's node. Introducing the notation of the preceding article, where we have put

ε, the moon's mean longitude;
l, its true geocentric longitude;
(l'), the motion of its true longitude in minutes of arc in $0^d.01$; and
θ, the longitude of its node;

we shall then have

$$\delta\lambda = \delta l - \delta L = \frac{(l')}{7.90}\delta\varepsilon - \delta L;$$
$$\delta\beta = \sin i \sec \beta \cos(l - \theta)(\delta l - \delta\theta)$$
$$= \sin i \sec \beta \cos(l - \theta)\left(\frac{(l')}{7.90}\delta\varepsilon - \delta\theta\right).$$

In the case of a central eclipse of the sun, we may put $\sec \beta \cos(l - \theta) =$ positive unity when the eclipse occurs near the ascending node, and negative unity when it occurs near the descending node, without an error of more than $\frac{1}{50}$ of the whole coefficient, and may take $\pm .995$ as its mean value. We may also suppose $\sin i = .090$. The value of $\delta\beta$ will then become

$$\delta\beta = \pm .0895\left(\frac{(l')}{7.90}\delta\varepsilon - \delta\theta\right).$$

Substituting these expressions for $\delta\lambda$ and $\delta\beta$ in the expression for $\delta\varDelta$, we find

$$\delta\varDelta = \frac{l'}{7.90}\left(\frac{d\varDelta}{d\lambda} \pm .0895\frac{d\varDelta}{d\beta}\right)\delta\varepsilon \mp .0895\frac{d\varDelta}{d\beta}\delta\theta + \frac{d\varDelta}{d\Pi}\delta\Pi - \frac{d\varDelta}{d\lambda}\varDelta L, \qquad (14)$$

in which the differential coefficients are to be taken from (12). This equation gives the condition which must be fulfilled by the corrections to the elements in order that the path of the shadow may be thrown to the north by the quantity $\delta\varDelta$.

The upper sign is to be used when the eclipse occurs at the ascending, the lower when it occurs at the descending node.

In this formula, we tacitly suppose the error of the moon's true longitude to arise only from that of its mean longitude, and neglect the effect of possible errors of the eccentricity and perigee. In practice, the datum which we are considering will be used only to determine the correction to the longitude of the node; but to do this, the correction to the true longitude must be supposed known. The mode of expressing this must depend on circumstances, and that which we now adopt is that to be used for the older eclipses.

§ 8.

OBSERVATIONS OF BULLIALDUS AND GASSENDUS.

The authorities for these observations are the printed works of the authors, namely:—

BULLIALDUS, *Astronomia Philolaica.* Paris, 1645.

GASSENDUS, *Opera, Tome IV, Commentarii de Rebus Coelestibus.*

I believe we must accord to BULLIALDUS the honor of being the first to actually observe the time of an occultation with a telescope. We begin with his observations. The times have been deduced from the observed altitudes, using the mean places of the stars given on the next two pages. The geographical positions of the places of observation of the two observers have been adopted as follows:—

Latin Name.	Modern Name.	Latitude.	Long. from Greenwich.	$\log \rho \sin \phi'$.	$\log \rho \cos \phi'$.
		° ′	m s		
. . . .	Paris . . .	48 52	9 21 E.	9.8747	9.8192
Juliodunum / Lodunum	Loudon . .	47 1	0 20 E.	9.8622	9.8344
Dinia . .	Digne . .	44 5	24 57 E.	9.8403	9.8570
Aquæ Sextiæ	Aix . . .	43 32	21 47 E.	9.8358	9.8610

It will be remembered that in making these observations the observers used no clock, but determined their time by observing the altitude of some well-determined object at the moment of the phenomenon. The star-positions used in reducing the observed altitudes of all the observers whose work is discussed in the following sections are shown in the following table. No refinement has been aimed at in their derivation, nor have the places been corrected for nutation and aberration. All the corrections which should be applied are completely masked by the probable errors of the observed altitudes.

Approximate Positions of Stars for Clock-error, carried back from the Positions of LE VERRIER.

(*Annales*, ii, p. [63].)

α ANDROMEDÆ.

Year.	Right Ascension. h	m	s	Declination. °	′
1650	23	50	25.48	+27	9.5
1700		52	58.11		26.0
1750		55	31.17		42.5
1800	23	58	4.66	27	59.1
1850	0	0	38.58	28	15.7
1900	0	3	12.93	+28	32.3

α ARIETIS.

Year.	h	m	s	°	′	″
1600	1	44	49.23	+21	31	46.7
1650		47	35.13	21	46	37.7
1700		50	21.51	22	1	22.7
1750		53	8.40		16	1.7
1800		55	55.78		30	34.8
1850	1	58	43.65		45	1.9
1900	2	1	32.02	+22	59	23.1

α CETI.

Year.	h	m	s	°	
1650	2	44	3.1	+2	40.9
1700		46	38.7	2	53.3
1750		49	14.5	3	5.6
1800		51	50.4		17.8
1850		54	26.5		29.9
1900	2	57	2.9	+3	41.8

ALDEBARAN.

Year.	h	m	s	°	′	″
1600	4	13	4.17	+15	37	37.4
1650		15	54.61		44	54.9
1700		18	45.32		52	1.0
1750		21	36.31	15	58	55.7
1800		24	27.57	16	5	39.0
1850		27	19.11		12	10.9
1900	4	30	10.92	+16	18	31.4

CAPELLA.

Year.	h	m	s	°	′
1600	4	47	18.16	+45	29.8
1650		50	56.94		34.3
1700		54	36.21		38.6
1750	4	58	15.97		42.7
1800	5	1	56.22		46.6
1850		5	36.97		50.3
1900	5	9	18.20	+45	53.8

β ORIONIS.

Year.	h	m	s	
1650	4	57	45.0	. . . . . .
1700	5	0	8.5	. . . . . .
1750		2	32.1	. . . . . .
1800		4	55.9	. . . . . .
1850		7	19.8	. . . . . .
1900	5	9	43.8	. . . . . .

SIRIUS.

Year.	Right Ascension. h	m	s	Declination. °	′
1650	6	29	43.2	−16	17.1
1700		31	55.5		20.2
1750		34	7.8		23.5
1800		36	20.1		27.1
1850		38	32.4		30.8
1900	6	40	44.7	−16	34.7

α ORIONIS.

Year.	h	m	s	°	′	″
1650	5	36	14.57	+7	17	7
1700		38	56.59		18	44
1750		41	38.69		20	10
1800		44	20.86		21	24
1850		47	3.11		22	27
1900	5	49	45.43	+7	23	18

β TAURI.

Year.	h	m	s	°	′	″
1600	5	1	5.11	+28	10	51
1650		4	13.38		14	50
1700		7	21.88		18	35
1750		10	30.61		22	7
1800		13	39.57		25	25
1850		16	48.77		28	30
1900	5	19	58.19	+28	31	21

PROCYON.

Year.	h	m	s	°	′	″
1600	7	18	19.00	+6	10	50
1650		20	56.75	6	4	18
1700		23	34.41	5	57	35
1750		26	11.97		50	41
1800		28	49.44		43	36
1850		31	26.81		36	20
1900	7	34	4.09	+5	28	53

POLLUX.

Year.	h	m	s	°	′	″
1600	7	20	43.08	+28	54	42
1650		23	48.62		48	47
1700		26	53.86		42	39
1750		29	58.81		36	19
1800		33	3.46		29	46
1850		36	7.81		23	1
1900	7	39	11.87	+28	16	3

REGULUS.

Year.	h	m	s	°	′	″
1650	9	49	39.78	+13	39	1.9
1700		52	20.91		24	53.8
1750		55	1.77	13	10	39.6
1800	9	57	42.37	12	56	19.4
1850	10	0	22.70		41	53.2
1900	10	3	2.77	+12	27	21.2

Approximate Positions of Stars for Clock-error, &c.—Continued.

β Leonis.

Year.	Right Ascension. h	m	s	Declination. °	′	″
1600	11	28	35.17	+ 16	48	9.7
1650		31	9.40		31	29.1
1700		33	43.43	16	14	47.6
1750		36	17.25	15	58	5.1
1800		38	50.87		41	21.7
1850		41	24.28		24	37.3
1900	11	43	57.49	+ 15	7	52.0

Spica.

Year.	h	m	s	°	′	″
1600	13	4	14.03	− 9	2	46.0
1650		6	50.24		18	51.7
1700		9	26.72		34	53.7
1750		12	3.47	9	50	51.9
1800		14	40.49	10	6	46.4
1850		17	17.77		22	37.1
1900	13	19	55.33	− 10	38	24.1

Arcturus.

Year.	h	m	s	°	′
1650	13	59	43.0	+ 21	1.7
1700	14	1	59.5	20	45.7
1750		4	16.0		29.7
1800		6	32.6	20	13.8
1850		8	49.2	19	57.9
1900	14	11	5.9	+ 19	42.2

α Coronæ Borealis.

Year.	h	m	s	°	′
1650	15	19	53.1	+ 27	55.6
1700		21	59.8		44.9
1750		24	6.6		34.3
1800		26	13.4		23.7
1850		28	20.3		13.4
1900	15	30	27.2	+ 27	3.1

α Lyræ.

Year.	Right Ascension. h	m	s	Declination. °	′
1650	18	25	5.8	+ 38	29.5
1700		26	47.2		31.7
1750		28	28.6		34.0
1800		30	10.1		36.3
1850		31	51.6		38.8
1900	18	33	33.2	+ 38	41.4

α Aquilæ.

Year.	h	m	s	°	′
1650	19	33	41.91	+ 7	59.2
1700		36	8.44	8	6.4
1750		38	34.94		13.7
1800		41	1.40		21.0
1850		43	27.83		28.6
1900	19	45	54.22	+ 8	36.2

α Cygni.

Year.	h	m	s	°	′
1650	20	29	31.00	+ 44	3.4
1700		31	12.95		13.6
1750		32	54.96		23.9
1800		34	37.02		34.3
1850		36	19.14		44.8
1900	20	38	1.31	+ 44	55.4

α Pegasi.

Year.	h	m	s	°	′
1650	22	47	22.06	+ 13	20.0
1700		49	50.74		35.9
1750		52	19.54	13	51.9
1800		54	48.47	14	7.9
1850		57	17.52		24.0
1900	22	59	46.70	+ 14	40.1

Observations of Bullialdus.

From *Astronomia Philolaica*, p. 159.

Anno 1623 Julij die 5 cum Lunae centrum altum esset g. $17\frac{1}{3}$ Parisiis observavi occultationem Spicae Virginis à ☽.

Bullialdus adds that the moon appeared 13′ north of the star in latitude; and having thence computed its position, he adds:—"fuit Hora Parisiis ex altitudine Spicae g. 17.7′. post meridiem ix. 30′." There is therefore some doubt whether the actual observation of altitude was made on the moon or on Spica. The correspondence between the difference of altitudes and difference of latitude is somewhat suspicious. The apparent places of the two objects are, as a first approximation:—

$$\text{Spica, A. R.} = 13^h\ 5^m\ 27^s;\quad \text{Dec.} = -\ 9^\circ\ 10'.$$
$$\text{Moon, A. R.} = 13^h\ 4^m\ 40^s;\quad \text{Dec.} = -\ 8^\circ\ 46'.$$

The place of the moon is that computed from HANSEN's Tables for $9^h\ 33^m\ 37^s$ Paris time, and corrected for parallax.

The local times thence deduced are:—

From alt. of Spica, $17^\circ\ 7'$, Sid. T. $= 16^h\ 27^m\ 15^s$; M. T. $= 9^h\ 33^m\ 18^s$.
Moon, $17^\circ\ 20'$ $16^h\ 26^m\ 58^s$; $9^h\ 33^m\ 1^s$.

The results agree well enough, but the fact is that at this time the tables, which cannot be $3'$ in error, show the apparent distance of the centre of the moon and Spica at this time to have been about $28'$, so that the star must have been some $13'$ distant from the moon's dark limb. The moon was then a few hours past her first quarter. Moreover, the moon was about $20'$ north of the star in latitude, so that there could not have been an occultation at all. Indeed, a careful reading of BULLIALDUS's deductions from his observation seems to indicate that he considered the two bodies to have the same longitude at the moment of the observation. Now, we must adopt one horn of this dilemma: either (1) we have to deal with such a blundering observer that he thought a star at the moon's limb when it was $23'$ distant, and in conjunction when the difference of longitude was some $20'$, and that when the dichotomized position of the moon was most favorable to the observation; or (2) he made a mistake in reading his altitude from the quadrant, and a consequent error of some 40^m in his computed time. The latter seems likely to be the correct explanation.

GASSENDUS at Digne was more successful. At the time when the altitude of Spica was $10^\circ\ 46'$ (local mean time, $10^h\ 32^m\ 40^s$), he says Spica was in the same right line with the cusps of the moon, the space being apparently equal to the diameter of Arcturus. This was 45^m in absolute time later than the observation of BULLIALDUS. On the whole, we can do nothing with this observation.

The next occultation is one of α Leonis, 1627, June 17, and is quoted by GASSENDUS as follows:—

Eandem Occultationem Ismael Bullialdus observavit Loduni (quod oppidum Pictanio est directè in Boream ac distat ab eo leucis usualibus 10 seu Germanicis 6½) hora 9 min 33 cum mempe ☽ a vertice foret 73 grad. 32 min. Nota Polarem elevationem illeic esse $48^\circ\ 1'$.

From the description, this place must be Loudon, the latitude assigned being 1° in error. It should be $47^\circ\ 1'$.

The altitude gives:—

Local mean time of occultation	$9^h\ 29^m\ 42^s$
Greenwich mean time	$9^h\ 29^m\ 22^s$.

Page 163.—Anno 1634. Julioduni apud Pictones cuius Meridianus removetur a Parisiensi occasum versus, quadrante fermè horae unius, observavi occultationem anguli orientalis quadrilateri Pleiadum quae & lucida Pleiadum dicitur interventu Lunae factam Decembris die 30 in distantia oculi Tauri à vertice p. 57. 18′. Hor. 5. 42′ vespere.

The position of Loudon is $\varphi = 47^\circ\ 1'$; $\lambda = 0^m\ 20^s$ east from Greenwich. The position of α Tauri was R. A. $= 4^h\ 15^m\ 3^s$; Dec. $= +15^\circ\ 43'$. We hence find:—

Hour-angle	$-3^h\ 54^m\ 30^s$
Sidereal time	$0^h\ 20^m\ 33^s$
Local mean time	$5^h\ 44^m\ 4^s$
Greenwich mean time	$5^h\ 43^m\ 44^s$.

Page 166.—Anno 1639. Aprilis die 7. in altitudine Procyonis g. 33. 52.′ Parisiis, id est Hor. 9. 8.′ T. A. Uraniburgi H. 9. 56.′ T. A. at medio H. 9. 54.′ vidi Lunam limbo obscuro occultare stellam quintae magnitudinis, quae est in origine cornu Borealis Tauri.

The result of the altitude of Procyon is:—

Local mean time	$9^h\ 9^m\ 42^s$
Local sidereal time	$10^h\ 13^m\ 13^s$
Greenwich mean time . . , . . . , ...	$9^h\ 0^m\ 21^s$.

The star occulted is τ Tauri.

Page 167.—Anno 1641. Aprilis die 13 alto versus occasum Humero Dextro Orionis g. 24 0′. Hor. 8. 8′ Parisiis, Luna mihi occultavit oculum Boreum ♉. (Locus Tychon ♊ g. 3. 27′.)

The resulting local times are:—

Sidereal	$9^h\ 42^m\ 7^s$
Mean	$8^h\ 13^m\ 4^s$.

The occulted star is ε Tauri.

Eclipses and occultations observed by GASSENDUS.

1621. Mense Maio, Die 20. (seu ut vulgus numerat, die 21. Manè) Eclipsin Solis hanc observabam Aquis-Sextiis. Modus autem Observationis fuit huiusmodi. Trajiciebantur Radii Solares in cameram ritè occlusam per probatum Telescopium foramini idoneo in suprema fenestra apparatum et fulcro ad motus positusque varios accommodato impositum.

Aderat ibi Germanus meus, qui Telescopium motitando, circellum lucis in concavo, seu inferiore vitro apparentem continuo restitueret, destineretque in medio.

Excipiebam ego Radios afferre plano solido, papyro candida obducto. Duxeram in eo Circulum, in quem radii cogerentur, ut in ellipsin non excurrerent. Diametrum pede Parisiensi aliquanto majorem diviseram in parteis aequaleis, seu Digitos 12. & quemlibet Digitum ita subdistinxeram in denas & quinas parteis, ut liceret etiam singula minuta per interstitia colligere.

Utramque etiam semi-circumferentiam in 180. parties distribueram (initio utriusque divisionis facto ab ipsa Radice primi digiti.) tum ut in magna occultatione liceret semper, usurpata heinc inde aequali ad interfectiones Circulorum lucis, & umbrae distantia, cogere radios in Circulum & nimorem maximum umbrae in Diametrum rejicere; tum ut exinde Diametrorum utriusque astri apparentium haberi posset mutua proportio.

Aderat praedictus Galterius in proxima Camera, assidue sectatus Solis altitudinem Quadrante Radii plusquam bipedalis. Erat verò penes me, qui statim atque appareret obscurationis vestigium, ictu parieti impacto, momentum ipsi significaret. Quare hoc signo notavit praecisè Solis altitudinem initio Eclipseos; neque ratione absimili eandem accuratè accepit in fine, seu quo momento obscuratio ex circulo prorsùs evanuit.

Omnibus ergo apprimè instructis, observaturi adfuimus ab hora circiter 6. ita scilicet verebamur, ne fallente calculo initium praeterlaberetur. Cumque ☉ tempore Eclipseos supponatur fuisse in 0. grad. 15. min. ♊ apparvit nobis praedicta die 20. Eclipseos. Initium hora 19. min. 5. sec. 28. elevato nempe ☉ 25. grad. 30. min.

Finis hora 21. min. 31. sec. 12. elevato scilicet ☉ 51. grad. 17. min.

Ac medium proinde contigit hora 20. min. 18. sec. 20.

Et tempus incidentiæ fuit hora 1. min. 12. sec. 52.

Et tota duratio horarum 2. min. 25. sec. 14.

Digiti ecliptici maximae obscurationis fuerunt 9. min. 23.

Et quia tum deficiebant utrimque ex circumferentia gradus 77. min. 30. heinc aequales visae arguuntur Luminarium Diametri.

Fuit Luna Soli Septentrionalis; quod circulos nobis citra telescopium temerari caeperit ad Austrum.

Fuit Coelum interspersum totum tempore Eclipseos rarioribus nubilis. Juvabant illa ut ☉ posset conspici oculo ferè inconniventi, & specillo quidem maximè. Conspectus verò est etiam innoxiè tum in speculo, tum in aqua limpida; cum utrobique tres viderentur exhiberi Soles, quasi tres Lunae corniculatae ex ordine positae, versis cornibus ad Occasum.

The altitudes give :—

Local mean time of beginning . . $19^h\ 1^m\ 37^s$; of end, $21^h\ 27^m\ 17^s$
Greenwich mean time of beginning . $18^h\ 39^m\ 50^s$; of end, $21^h\ 5^m\ 30^s$.

1627. Mense Junio, Die 17. Vesperi, hanc occultationem Cordis Leonis à Luna observabam Diniae, cùm scilicet foret Cauda ♌ alta ad Occasum 25. grad. 13. min. hoc est, hora 10. min. 30. praecisè (utebar dicto iam antè Quadrato, cuius umbra recta, seu tangens exhibuit parteis 4710) Luna, tum corniculata limbo suo Orientali, seu parte obscura Cor. ♌ subiit.

Porrò tum tectura triente à cornu inferiori; tandem verò texit non multò ampliùs quadrante.

Observata est autem non nudo solùm visu, quo Stella videbatur Lunam, quasi adrependo, radere; verùm etiam per Telescopium, quo distantiola quaeque ad occultationem usque distinctè percepta est.

The altitude of β Leonis gives :—

Local mean time of occultation . . . . $10^h\ 30^m\ 0^s$
Greenwich mean time . . . . $10^h\ 5^m\ 3^s$.

1630. Caeterum copiam à Schickardo nostro tibi iam existimo factam meae illius observationis circa Eclipsin Solis nuperam diei 10. Junii.

Page 545 —Nisi fuerit, scito nobis in hac Civitate (cujus latitudo est 48. grad. 52. min.) illius initium contigisse Sole ad occasum alto grad. 14. min. 40. seu horâ post meridiem 6. min. 16½. Finem videre non potuisse, proper Solis occubitum, cùm duorum propè digitorum foret adhuc obscuritas. Medium, quatenus licuit, observatum proximè fuisse Sole adhuc elevato grad. 6. min. 20. seu horâ circiter 7. min. 12.

The place of observation was Paris. The altitude gives :—

Local mean time of beginning . . . . June 10, $6^h\ 15^m\ 1^s$
Greenwich mean time of beginning . . . . . June 10, $6^h\ 5^m\ 40^s$.

Page 547.—1632. Februarii, die 5.—Credebam etiam facilè fore, ut Luna duntaxat Martem stringeret: nisi quod ad constitutionem Poli Eclipticae respiciens, non omninò desperabam, quin vel tantillum occultaret. Nec vero vana fuit spes. Siquidem iam sub hor. 3. cùm plurimum illi quasi adrepsisset, ac Mars proxime accessisset ad verticalis Lunae planum, tum demum Luna Martem occuluit. Contigit ista occultatio, cùm limbus illae Lunae supremus foret altus ad occasum grad. 44. min. 17. & eodem tempore Arcturus foret altus ad exortum grad. 56. min. 10. Expectato posteà egressu, etsi vapores iam fuerant longè ampliùs densiores facti, variegataque irradiatio circum Lunam diffundebatur; apparvit tamen emergens in multa iam inclinatione ultra planum verticalis, cùm idem limbus Lunae supremus esset altus ad occasum gr. 39. min. 57. eodemque momento ad ortem foret Lucida Lyrae alta grad. 31. min. 54.

The observations give :—

Immersion, from altitude of Arcturus, Local M. T. $15^h\ 18^m\ 39^s$; G. M. T. $15^h\ 9^m\ 18^s$.
Emersion, from altitude of α Lyræ, Local M. T. $15^h\ 47^m\ 31^s$; G. M. T. $15^h\ 38^m\ 10^s$.

Eclipse of 1633, *April* 8, *observed at Digne.*

Phases Eclipseos.	Quantitas Defectus.		Gradus hinc inde deficientes	Gradus inclinatio. Diametrorum ad Vertic.	Alt. ☉ in partibus.	Id est.		Seu respectu habito tum refr. tum parallaxeos.		Unde colligitur fuisse.		Proportio Diametri ☾ ad Diametr. ☉ Sit ☉. Sem. 15. m. 20. sec. & Sem. ☾	
	dig.	m.	gr. m.		V. R.	gr.	m.	grad.	min.	hor.	min.	min.	sec.
1.	4.	30.	50.	.	5150.	25.	15.	27.	12.	3.	56.	15.	2.
2.	5.	42.	58.	.	. .	.	.	.	.	.	.	15.	0.
3.	7.	0.	65.	32.	4050.	22.	3.	22.	0.	4.	26.	15.	8.
4.	7.	30.	68.	38.	3950.	21.	33.	21.	29.	4.	29.	15.	8.
5.	8.	6.	70.	50.	3800.	20.	48.	20.	43.	4.	33½.	15.	17½.
6.	8.	12.	71.	60.	3720.	20.	24.	20.	19.	4.	36.	15.	15.
7.	8.	18.	72.	62.	3540.	19.	30.	19.	25.	4.	41.	15.	12.
8.	8.	18.	73.	72.	3450.	19.	2.	18.	56.	4.	43½.	15.	7.
9.	8.	6.	70.	85.	3300.	18.	16.	18.	9.	4.	48.	15.	17½.
10.	7.	42.	68.	107.	3030.	16.	51.	16.	44.	4.	56.	15.	15.
11.	7.	30.	67.	112.	2920.	16.	17.	16.	9.	4.	59.	15.	15.
12.	7.	12.	65.	117.	2850.	15.	54.	15.	46.	5.	1.	15.	17.
13.	6.	48.	64.	122.	2800.	15.	39.	15.	31.	5.	3.	15.	7.
14.	6.	36.	62.	125.	2750.	15.	23.	15.	15.	5.	4.	15.	12.
15.	6.	12.	60.	128.	2670.	14.	57.	14.	48.	5.	7.	15.	10.
16.	5.	30.	55.	132.	2560.	14.	22.	14.	13.	5.	10.	15.	12.
17.	5.	18.	53.	134.	2450.	13.	46.	13.	37.	5.	13.	15.	15.
18.	5.	0.	52.	136.	2350.	13.	13.	13.	4.	5.	16.	15.	10.
19.	4.	30.	50.	138.	2260.	12.	44.	12.	35.	5.	19.	15.	2.
20.	4.	18.	48.	140.	2230.	12.	34.	12.	25.	5.	20.	15.	5.
21.	3.	42.	45.	141.	2160.	12.	11.	12.	1.	5.	22.	15.	6.
22.	3.	0.	39.	142.	2060.	11.	38.	11.	28.	5.	25.	15.	2.
23.	2.	42.	37.	143.	2000.	11.	19.	11.	9.	5.	27.	15.	2.
24.	2.	0.	35.	145.	1900.	10.	45.	10.	34.	5.	30.	14.	52.
25.	1.	36.	30.	147.	1740.	9.	52.	9.	41.	5.	35.	14.	57.
26.	0.	54.	20.	148.	1600.	9.	5.	8.	54.	5.	93½.	15.	10.
27.	Finis.		0.	150.	1420.	8.	5.	7.	53.	5.	45.	.	.

The results of the observations will be given in discussing the eclipses.

1635. Aug. 26.—Occultatio praecedentis duarum Caudae ☋ à ☾. quia Keplerus monuerat fore ut ☾ Stellas Caudae ☋ tegeret nobis, idcirco attendendum duxi quid hac de re contingeret. Et nubes quidem perexiguam reliquerant spem quicquam observandi, ac potissimum circa praecedentem duarum ☋ in tanta ☾ vicinia, ob illius exilitatem; verùm tametsi obstiterunt, quo minus relicta à ☾ detegi usquam potuerit, permisere tamen ipsius conspectum, quo momento obtegi coepit. Variè, ac non sine labore sectatus illam fueram etiam maximo Telescopio, ob universi propemodum aëris nubilositatem; sed favore eximio distinctissimè visa est à sensibili interstitio, quousque paenè contigua fuit illustrato margini orientali ☾ ultra quem (adhuc asperatum) tantillum supererat marginis illius obscuri, praeter quem facta tandem est.

Luna itaque subiit Stellam è regione superioris partis Maculae grandiusculae, & aliquatenus rotundae, quae est ad laevam umbilici, hoc est infra medium orientalis marginis parte fere duodecima totius ambitus Lunaris.

Fuit autem tunc lucida ♈ jam elevata ad Ortum 3350. seu 18. grad. 31. min. unde proditur hora 9. min. 47. Fuit & margo superior ☾ altus 4940. seu 26. gr. 17. min. ac proinde Stella occultata 25. grad. 57. min. proximè, unde proditur hora 9. min. 50½. Fuit denique altitudo Capitis Andromedae 9400. seu 43. grad. 14. min. unde proditur hora 9. min. 50. crediderim horam 9. min. 49.

The results from the three altitudes of stars are:—

From δ Arietis: Local mean time, $9^h\ 47^m\ 49^s$; hour-angle, $-\ 5^h\ 39^m\ 33^s$.
From α Andromedæ: Local mean time, $9^h\ 52^m\ 25^s$; hour-angle, $-\ 3^h\ 39^m\ 29^s$.
From γ Capricorni: Local mean time, $9^h\ 57^m\ 34^s$; hour-angle, $-\ 1^h\ 4^m\ 24^s$.

The most probable mean time, $9^h\ 50^m\ 12^s$.

Occultations of the Pleiades.

1637. Mart. die 29. Aquis Sextiis.—Tum quia ☾ jam evadebat Stellae propinqua admodum divertere alio non placuit. Itaque jussus est Agarratus assiduè sectari altitudinem ipsius Aldebarae dum ipse Telescopio ad occultationem attendo. Caeterùm

Occultatio Stellae anguli occidui in □ Pleiadum contigit, cùm altitudo Aldebarae foret 20. grad. 55 min. ac proinde hora 8. min. 44.

Occultatio Stellae anguli Borei in □ Pleiadum contigit cùm Aldebarae altitudo foret 14. grad. 50. min. ac proinde hor. 9. min. 19. consequenter autem fuit altitudo ☾ superiore margine 10. grad. 50. min. & lucidae Pleiadum 11. grad. 0. min. atque adeo hora . min. .

Occultatio Stellae anguli Austrini in □ Pleiadum contigit, cùm Aldebarae altitudo foret 13. grad. 10. min. ac proinde hor. 9. min. 26. & Stellae in extremo cornu Boreo ♉ 29. grad. 30. min. seu hora . min. . Fuit & consequenter altitudo ☾ 9. grad. 25. min.

Occultatio Stellae anguli ortive in □ seu lucidae Pleiadum contigit cùm altitudo extremi cornu Borei ♉ foret 26. grad. 35. min. ac proinde hor. 9. min. 45. fuit consequenter altitudo Aldebarae 10. grad. 10. min. unde hora . min. . & consequenter ☾ 6. grad. 50. min.

The altitudes give:—

Immersion of Electra; Alt. of Aldebaran: Local mean time, $8^h\ 48^m\ 58^s$.
Immersion of Maja; Alt. of Aldebaran: Local mean time, $9^h\ 22^m\ 47^s$.
Immersion of Maja; Alt. of η Tauri: Local mean time, $9^h\ 23^m\ 18^s$.
Immersion of Merope; Alt. of Aldebaran: Local mean time, $9^h\ 32^m\ 3^s$.
Immersion of Merope; Alt. of β Tauri: Local mean time, $9^h\ 33^m\ 10^s$.
Immersion of η Tauri; Alt. of β Tauri: Local mean time, $9^h\ 49^m\ 41^s$.
Immersion of η Tauri; Alt. of Aldebaran: Local mean time, $9^h\ 48^m\ 57^s$.

1638. Januario. Die 24.—Vesperi, appulsus, & occultatio Pleiadum à ☾ luctandum quidem fuit cum vento, sese ob nimiam violentiam quoquoversum insinuante, itemque cùm eo frigore, quo intensius meminit nemo; sed non licuit spectaculum dimittere inobservatum. Paucis itaque ☾ transiit proximè angulum occiduum △ Pleiadum suo angulo Boreo, cum distantia quanta apparuit inter superiorem ejus limbum & nigrescentem Phascolum, seu parte diametri Lunaris quasi $\frac{1}{10}$. idque alto proximè Polluce ad ortum 45. grad. 0. min. hoc est hora 7. min. 23.

☾ texit angulum Austrinum △ Pleiadum parte obscura, diametrique suae quasi $\frac{1}{5}$. à Boreo sui angulo, nempe è regione globuli illius majoris, quem Carthusiam dicere soleo, aut tantillum inferius; idque Polluce alto 46. grad. 30. min. hoc est hora 7. min. 31.

☾ texit lucidam Pleiadum, seu angulum △ ortiuum parte diametri quasi $\frac{1}{5}$. à Borea sui cuspide, scilicet in medio superioris maris. Erat autem tunc Lucida in ore ♌ alta 32. grad. 15. min. (Pollux quippe incommodè deinceps observabilis, divergereque cogebat ventus) hoc est hora 7. min. 52.

We have from the altitudes:—

Immersion of Merope; alt. of Pollux: Local mean time, $7^h\ 39^m\ 34^s$.

The certain identification of the other star offers difficulty:—

If the star be α Leonis, we have local mean time about 9^h 30^m (too late).
If the star be $\varkappa$ Leonis, we have local mean time about 8^h 4^m 27^s.
If the star be λ Leonis, we have local mean time about 8^h 22^m 29^s.
If the star be ε Leonis, we have local mean time about 8^h 35^m 10^s.

Occultation of μ Geminorum observed at Digne.

1638. Decembri. Die 21.—Ceterum cum ☾ jam prorsùs exueret superstite millam obtenebrationem in situ paenè heic descripto, ita promota intereà fuit versus eam Stellam, quae est in extremo pede Castoris, anteceditve aliam in pede procedentis ♊, ut illam media subierit, terraeque eripuerit, quae mox ante ipsi eripuerat Solem; scilicet ipsam occuluit paulò infrà maculam parvam quam initio in parte ☾ orientali descripsimus, ac tanto quidem intervallo, quantum macula longa est; adeò ut locus fuerit quasi medius inter primam defectionem, & recuperationem lucis.

Fuit autem tunc humerus dexter Orionis ad Occidentem adhuc altus 285. seu 15. grad. 54. min. atque idcirco exstitit hora 16. min. 37.

The altitude gives:—

Local mean time, 16^h 36^m 34^s; Greenwich mean time, 16^h 11^m 37^s.

Eclipse of the Sun observed at Aix, 1639, *June* 1.

1639. Mense Junio, Die 1. A meridie, Eclipsis ☉. Fuerat Coelum vespere toto Diei 30. obscurum; à meridie verò diei 31. etiam pluvium.

Hoc manè varium existit, à meridie potius serenum. In ipso meridie famulus áttendens ad ☉ altitudinem, deprehendit illam quadrante ligneo pedum prope trium, quo usurus eram, 68. grad. 38. min. unde quia ☉ fuit in 16. grad. 36. min. ♊ cum declinatione Boreas 22. grad. 7. min. colligitur altitudo Poli 43. grad. 36. min. major aequo tribus, vel 4. minutis. Apparata intereâ est scena in supremo Solario, unde Eclipsis observaretur, inductàque in eam machina, qualem Diniae quoque habueram circa Eclipsin anni 1633. heinc par fuit observandi modus, sed non aequa felicitas propter usurpatum Telescopium majus, quod speciem Solis in circulo tremulam nimis exhibuit, propterque ipsam machinam, quae non satis aequabilis secundum omnem motionem fuit. Effectum nempe exinde est, ut tametsi Corberanus dirigeret machinam, ipse circulum temperarem, adjutarentque etiam viri in civitate principes, (alias profectò importuni) in adnotandis partibus tum ipsius diametri, quà umbrae Lunaris maximus tumor pertingebat, tum circumferentiae, qua heinc inde arcus conspicuus eiusdem umbrae intersecabat; nihilominus species Solis extremorum mobilitate oculos saepè deluserit et partibus hujusmodi non satis constanter designatis, diametrorum proportio aucupari potissimùm expetieram, prodita fuerit inconstanter.

Non distinxeram porrò diametrum in duodenos digitos, digitorùmque minuta: sed in parteis 100. & duplatione in 200. ut ex radio supposito 100. vel ampliatione 100000. calculus esset brevior ad retexendum eam proportionem cùm & reductio in digitos futura esset perfacilis. Jam & famulus extra scenam attendit continuò ad altitudinem ☉ decrescentem, ipse intereà continuò attendi ad oppositum Soli circulum (interposui etiam plerumque candidissimam papyrum) ab hora paene tertia ne, si foret praeccupatio, initium invisum praeterlaberetur. Tantum verò abfuit ut tempus praeoccupatum fuerit quin retardatius longè fuit, quam omnes sive Tabulae, sive Ephemerides indicarent. Praetereo autem per id tempus nullam extitisse maculam in ☉. Cum primùm porro circulus temerari sursum ad dextram est visus, requisivi ex famulo Solis altitudinem. Respondit ipse momento post eam esse 28. grad. 30. min. unde indicata est hora 4. min. 44½. quia vero inter dignoscendum num esset vel quaedam marginis inaequalitas, vel umbra ☾ subiens (adde & inter respondendum) tantum temporis est elapsum, ut tantillus intereà defectus occupare potuerit $\frac{1}{200}$. diametri; idcircò visum est initium posse exquisitè referri ad hor. 4. min. 44. en nunc seriem observationis, cum deductis per calculum.

Partes 100. diametri deficientes.	Seu ex reductione in digitos et minuta. dig.	m.	Gradus circumferentiae heinc inde deficientes. grad.	Unde colligitur diam. partium ☾ 100.	Et diam. ⊙ supposita 30. m. 24. sec. colligitur diam. ☾. min.	sec.	Altitudo ⊙ supra horizontem. gr.	m.	Momenta inde elicita. hor.	min.
Initiū.	.	.	.	.	.	.	28.	30.	4.	44
5.	0.	36.	18.	96.	29.	11.	28.	0.	4.	47.
7.	0.	50.	20.	77½.	23.	34.	27.	40.	4.	49.
10.	1.	12.	25.	89.	27.	3.	27.	20.	4.	51.
12.	1.	26.	28.	95½.	29.	2.	27.	0.	4.	52½.
14.	1.	41.	30.	93.	28.	16.	26.	37.	4.	55.
18.	2.	11.	35.	104.	31.	37.	26.	10.	4.	57.
20.	2.	24.	37.	101.	30.	42.	26.	2.	4.	58.
22.	2.	38.	38.	94½.	28.	44.	25.	30.	5.	1.
25.	3.	0.	40.	90½.	27.	31.	25.	24.	5.	1½.
27.	3.	14.	43.	99.	30.	6.	25.	0.	5.	4.
30.	3.	36.	45.	96½.	29.	20.	24.	40.	5.	5.
33.	3.	58.	47.	95.	28.	52.	24.	25.	5.	7.
36.	4.	19.	50.	99.	30.	6.	24.	5.	5.	9.
38.	4.	34.	51.	97.	29.	29.	23.	40.	5.	11.
39.	4.	41.	52.	98.	29.	48.	23.	30.	5.	12.
39½.	4.	45.	52.	96½.	29.	20.	23.	20.	5.	13.
41½.	5.	0.	54.	99.	30.	6.	23.	0.	5.	15.
42½.	5.	6.	55.	100.	30.	24.	22.	55.	5.	15½.
46½.	5.	35.	57.	97½.	29.	38.	22.	30.	5.	18.
47.	5.	38.	57.	96½.	29.	20.	22.	15.	5.	19.
50.	6.	0.	60.	100.	30.	24.	22.	0.	5.	21.
55.	6.	36.	65.	104½.	31.	46.	21.	2.	5.	26.
60.	7.	12.	67.	101.	30.	42.	20.	30.	5.	29.
61½.	7.	23.	68.	101.	30.	42.	20.	20.	5.	30.
62.	7.	26.	67.	98.	29.	48.	20.	3.	5.	31½.
62,	7.	26.	68.	100½.	30.	33.	19.	45.	5.	33.
64.	7.	41.	68.	98.	29.	48.	19.	30.	5.	34½.
65.	7.	48.	70.	100½.	30	33.	19.	25.	5.	35.
66½.	7.	59.	70.	99.	30.	6.	19.	5.	5.	37.
67.	8.	2.	71.	100.	30.	24.	18.	55.	5.	38.
68.	8.	10.	72.	101.	30.	42.	18.	36.	5.	40.
67½.	8.	6.	70.	98.	29.	48.	18.	0.	5.	43.
68.	8.	10.	70.	98.	29.	48.	17.	16.	5.	47.
68.	8.	10.	70.	98.	29.	48.	16.	40.	5.	51.
67.	8.	2.	69.	97.	29.	29.	.	.	.	.
66.	7.	55.	68.	96½.	29.	20.	16.	0.	5.	54½.
62.	7.	26.	68.	100½.	30.	33.	15.	30.	5.	57½.
59.	7.	5.	66.	100.	30.	24.	15.	0.	6.	0.
58.	6.	58.	65.	90½.	30.	15.	14.	40.	6.	12.
55.	6.	36.	64.	102.	31.	0.	13.	58.	6.	6.
52.	6.	15.	60.	96.	29.	11.	13.	35.	6.	8½.
50.	6.	0.	59.	97.	29.	29.	13.	25.	6.	9½.
48.	5.	46.	58.	98.	29.	48.	13.	5.	6.	11.
46.	5.	31.	57.	99.	30.	6.	12.	48.	6.	13.
39.	4.	41.	54.	107.	30.	32.	.	.	.	.
34.	4.	5.	49.	86.	26.	9.	.	.	.	.

Partes 100. diametri deficientes.	Seu ex reductione in digitos et minuta. dig.	m.	Gradus circumferentiae heinc inde deficientes. grad.	Unde colligitur diam. partium ☾ 100.	Et diam. ☉ supposita 30. m. 24. sec. colligitur diam. ☾. min.	sec.	Altitudo ☉ supra horizontem gr.	m.	Momenta inde elicita. hor.	min.
32½.	3.	54.	48.	102.	31.	0.	11.	18.	6.	22.
31.	3.	43.	47.	103½.	31.	28.	11.	0.	6.	23½.
28.	3.	24.	44.	100.	30.	24.	10.	37.	6.	25½.
27.	3.	14.	43.	99.	30.	6.	10.	27.	6.	27.
25.	3.	0.	40.	90½.	27.	31.	10.	10.	6.	28½.
23.	2.	46.	38.	89.	27.	3.	10.	0.	6.	29½.
20.	2.	24.	37.	101.	30.	42.	8.	45.	6.	31.
19.	2.	17.	35.	98.	29.	48.	.	.	.	.
17.	2.	2.	33.	92.	27.	58.	9.	30.	6.	31½.
12.	1.	26.	28.	95½	29.	2.	9.	0.	6.	35½.

Hactenus tenuiora solum nubila fecerant negotium; ex hoc verò tempore suborta, ac sensim ascendens ab occasu crassissima nubes ita Solem subiit, texitque, ut factus exinde fuerit inconspicuus.

Sequitur Bullialdi observatio, quae est peracta Parisiis, opposito Soli circulo, cujus diameter esset paenè bes pedis Parisiensis. Et diametrum diviserat quidem in parteis 24. circulum in parteis 180. at quod solus Phaseis notaret, altitudines caperet, & singula operaretur, non potuit simul ad diametrorum inclinationes attendere. Quod superest observationem certum ad minutum habendam perscripsit, & hac forma ad me transmisit.

Altitudines ☉ observate. gr.	m.	Altitudines parall. & Refract. correctae. grad.	min.	sec.	Momenta ex altitudinibus correctis. hor.	min.	sec.	Digiti Ecliptici.		
32.	35.	32.	35.	59.	4.	21.	4.	.	.	Coepit ☾ stringere marginem ☉.
31.	30.	31.	30.	50.	4.	27.	39.	1½.		
28.	57.	28.	57.	25.	4.	43.	12.	4.	0.	
27.	56.	27.	56.	21.	4.	49.	24.	5.	0.	
26.	56.	26.	56.	7.	4.	55.	31.	6.	0.	
25.	12.	25.	11.	36.	5.	6.	8.	7½.		
23.	55.	23.	54.	19.	5.	14.	0.	8.	0.	
21.	51.	21.	49.	37.	5.	26.	47.	8¾.		Maximus defectus.
20.	0.	19.	57.	44.	5.	38.	17.	8.	0.	
18.	50.	18.	47.	7.	5.	45.	14.	7.	0.	
18.	8.	18.	4.	35.	5.	50.	3.	6.	0.	
16.	36.	16.	31.	31.	5.	59.	46.	4½.		
16.	2.	15.	57.	17.	6.	3.	37.	4.	0.	
15.	36.	15.	31.	1.	6.	6.	5.	3½.		
15.	8.	15.	0.	52.	6.	9.	16.	3.	0.	
14.	26.	14.	20.	31.	6.	13.	33.	2.	0.	
13.	38.	13.	32.	0.	6.	18.	43.	1.	0.	
12.	41.	12.	34.	49.	6.	24.	49.	0.	0.	Finis; vel potius uno scrupulo citius.

Eclipse of 1652, April 7, observed at Digne.

1652.—Mense Aprili, die 8. ante meridiem eclipsis ⊙ Diniae novendecim ante annis die quoque Aprilis 8. observâram aliam suo superius loco descriptam. Eadem sum proinde usus machina, eadem observandi ratione; nisi quod & scenam collocandae machinae, & locum proximum captandis Solis altitudinibus in ipsismet Praeposituræ aedibus apparaveram. Quod providissem porro fore, ut finis eclipseos sub meridiem contingeret, ac proinde tempus ex parum variatis Solis altitudinibus satis exquisite discerni non posset; idcirco apparâram Sciotericum, quod quas pôsset suppetias ipsis altitudinibus ferret. Quod vererer autem, ne ingravescente, quae ab aliquot diebus me habebat febricula, adesse observando non possem; ideo commonstrâram non modo Taxili, Tornatori, fidoque Amanuensi Antonio Poteriae, sed insuper etiam juveni praeclaro Francisco Bernerio, quem totis duobus mensibus, cum me invisisset, jam detinebam, quid unicuique praestandum foret, ut meae vices supplerentur. Fuit mihi tamen propitium numen, ut possem non modo interesse, sed regere quoque intra tympanum, circulum eclipseos typum exhibentem, utpote excipientem trajectos telescopio unà cum tumore umbrae lunaris Solis radios, ac adnotare simul formam, quantitatemque ipsius defectus; adjutabat vero adnotanto praeter Tornatorem eximius Joannes Franciscus Augerius Regius cognitor, & rerum bonarum apprime studiosus, qui unà cum optimo Lauteretio fieri particeps spectaculi voluit. Moderabatur interea Bernerius machinam manubrio, Taxilis extra scenam quadratum, Poteria ad quidvis famulabatur. Ne longum autem faciam, rem totam pro more sic uno prospectu ab oculos pono.

Cum tempora heic habeantur ex Solis altitudinibus deducta, taceri non debet Sciotericum exhibuisse initium duobus prope minutis ante, finem duobus, aut tribus post. Et quod ad initium quidem attinet, altitudini magis fido; quod ad finem autem spectat, magis haereo; ac potissimum, quia memini, tametsi perpendiculum visum est constantius haerere ad partem umbrae versae 741. excurrisse tamen interdum versus 740. & ad Sciotericum cum respexi, umbra styli satis praecise ad meridianam lineam quadrabat; quod excessisse enim pilum videbatur, id spectare potuit ad tempus, quo ad quadratum me attentum praebui. Utcumque fuerit ex deducta serie, contigit eclipseos.

Initium hor. 9. min. 43. medium hor. 10. min. 51. finis hor. 11. min. 58.
Sicque fuit tota duratio hor. 2. min. 15. dimidium hor. 1. min. 7½.
Fuere autem maximae obscurationis digit. 9. min. 24.

Diametrorum proportio satis inconstans; veruntamen, ne eam, quae habetur circa initium, ac finem moror, videtur omnibus expensis, & ob Phaseis aliquot, quas commemini diligentius notatas posse rem ita definiri, ut si diameter ⊙ supponatur fuisse min. 30. sec. 4. diameter ☾ fuerit min. 30. sec. 55. sin amplius, aut minus pari proportione. Lubet porro apponere schema, juxta quod proportionem deduxi.

Cum subinde observationem, calculumque eclipseos communicassem cum optimò Valesio, rescribens ipse die 27. Gratianopoli perscripsit treis observationes duas Parisiis seorsim peractas, alteram a nostro Bullialdo, alteram a meo quondam Agarrato, ac Morino; tertiam Avenione a nobili, communique nostro San-Legerio. Parisiensis sic fuerunt

Bullialdo.	Agarrato & Morino.	Utrique.
Initium hor. 9. min. 12. sec. 47.	hor. 9. min. 30.	
Medium hor. 10. min. 25. sec 19.	hor. 10. min. 45.	Digiti ecliptici 10. min. 20.
Finis hor. 11. min. 42. sec. 14.	hor. 12. min. 12.	

Avenionensis autem sic	Initium hor. 9. min. 33.	De quantitate eclipseos
	Medium hor. 10. min. 50.	nihil perscripsit.
	Finis hor. 11. min. 53.	

Eclipse of 1652, *April* 7, *observed by* GASSENDUS *at Digne.*

Phases defectus	Altitudo ⊙			Tempora inde elicita		Semiarcus deficientis orae ⊙	Oualium diamet. ⊙ 720 taliū elicitur semi-diamet. ☾	Heinc diam. ⊙ supposita 30 min. 40 sec. deducitur semidiam. ☾		Ac proinde ipsa semi-diameter ☾	
	Umbra recta										
Digiti		grad.	min.	hor.	min.	grad.		min.	sec.	min.	sec.
Initiu	92500	42	46	9	43	.	.	.	.	.	.
$0\frac{1}{2}$	939	43	12	9	46	16	628	26	45	13	22
1.	955	43	40	9	49	24	764	32	32	16	16
$1\frac{1}{2}$	962	43	54	9	51	29	724	30	50	15	25
2.	977	44	20	9	54	34	748	31	50	15	55
$2\frac{1}{2}$	991	44	44	9	57	38	740	31	31	15	45
.	V. V.	.	.	.	.	.	.	.	.	.	.
3.	999	45	2	10	0	42	751	32	0	16	0
$3\frac{1}{2}$	991	45	16	10	2	45	719	30	38	15	19
4.	977	45	40	10	5	48	698	29	44	14	52
$4\frac{1}{2}$	965	46	1	10	8	52	743	31	39	15	50
5.	948	46	31	10	12	55	742	31	36	15	48
$5\frac{1}{2}$	935	46	54	10	15	58	739	31	29	15	45
6.	924	47	14	10	18	$60\frac{1}{2}$	730	31	6	15	33
$6\frac{1}{2}$	915	47	32	10	21	64	746	31	46	15	53
7.	900	48	0	10	25	67	740	31	31	15	45
$7\frac{1}{2}$	891	48	17	10	28	70	749	15	44	15	57
8.	878	48	43	10	32	73	751	32	0	16	0
$8\frac{1}{2}$	865	49	9	10	37	76	750	31	56	15	57
9.	849	49	39	10	42	79	748	31	51	15	55
$9\frac{2}{10}$	838	50	3	10	45	80	749	31	54	15	57
$9\frac{3}{10}$	828	50	13	10	48	81	753	32	5	16	$2\frac{1}{2}$
$9\frac{4}{10}$	824	50	30	10	50	82	753	32	5	16	2
$9\frac{4}{10}$	822	50	34	10	51	82	753	32	5	16	2
$9\frac{4}{10}$	820	50	38	10	52	83	762	32	27	16	14
$9\frac{3}{10}$	818	50	43	10	53	82	753	32	5	16	2
$9\frac{1}{10}$	814	50	52	10	55	81	765	32	35	15	18
9.	809	51	1	10	58	80	762	32	27	16	14
$8\frac{1}{2}$	799	51	22	11	3	75	741	31	34	15	47
8.	787	51	47	11	8	73	751	32	0	16	0
$7\frac{1}{2}$	781	52	1	11	12	69	734	31	16	15	38
7.	776	52	12	11	16	$65\frac{1}{2}$	723	30	47	15	24
$6\frac{1}{2}$	770	52	22	11	19	63	726	30	55	15	27
6.	765	52	35	11	23	60	720	30	40	15	20
$5\frac{1}{2}$	762	52	42	11	26	58	739	31	29	15	45
5.	757	52	53	11	30	55	742	31	36	15	48
$4\frac{1}{2}$	754	52	59	11	33	53	775	33	1	16	30
4.	752	53	4	11	36	49	753	33	5	16	$2\frac{1}{2}$
$3\frac{1}{2}$	749	53	10	11	39	46	771	33	51	16	25
3.	747	53	14	11	42	42	751	32	0	16	0
$2\frac{1}{2}$	741	53	18	11	44	38	740	31	31	15	45
2.	744	53	21	11	47	34	748	31	51	15	55
$1\frac{1}{2}$	743	53	23	11	49	28	743	27	24	13	42
1.	742	53	$24\frac{1}{2}$	11	52	23	672	28	20	14	20
$0\frac{1}{2}$	742	53	26	11	55	16	628	26	45	13	22
Finis.	741	53	27	11	58	.	.	.	.	.	.

Observatio deliquii Solaris die 12. *Augusti* 1654. *Aquis-Sextiis facta ab Honorato Galterio.*

Obscuratio Solis								Recuperatio luminis							
Digiti	Altitudo ⊙ gr.	min.	V. gr.	min.	Tempora hor.	min.	sec.	Digiti.	Altitudo ⊙ gr.	min.	V. gr.	min.	Tempora. hor.	min.	sec.
Initiū.	35.	30.	54.	57.	3.	39.	12.	7.	49.	7.	34.	27.	2.	18.	.
1.	36.	15.	53.	39.	3.	34.	9.	.	50.	20.	32.	25.	2.	9.	10.
½.	.	.	.	.	.	.	.	6.	51.	10.	30.	58.	2.	4.	.
2.	.	.	.	.	.	.	.	.	52.	2.	29.	15.	1.	57.	.
½.	.	.	.	.	.	.	.	5.	52.	26.	27.	27.	1.	49.	6.
3.	38.	35.	50.	32.	3.	22.	2.	.	53.	12.	27.	21..	1.	49.	2.
½.	39.	45.	48.	50.	3.	15.	5.	4.	53.	50.	26.	8.	1.	44.	.
4.	41.	10.	46.	46.	3.	7.	.	.	54.	21.	25.	9.	1.	40.	.
½.	.	.	.	.	.	.	.	3.	54.	55.	24.	1.	1.	36.	1.
5.	41.	35.	46.	8.	3.	4	8.	.	55.	20.	23.	9.	1.	32.	9.
½.	42.	35.	44.	40.	2.	58.	10.	2.	55.	33.	22.	42.	1.	30.	12.
6.	43.	6.	43.	53.	2.	55.	8.	.	55.	58.	21.	50.	1.	27.	5.
½.	.	.	.	.	.	.	.	1.	56.	18.	21.	14.	1.	25.	.
7.	45.	35.	40.	6.	2.	40.	6.	.	57.	.	19.	31.	1.	18.	.
½.	47.	14.	37.	30.	2.	30.	.	Finis.	57.	20.	18.	45.	1.	15.	.
8.	48.	10.	36.	1.	2.	24.	1.	.	.	.	.	.	.	.	.

Initium hor. 8. min. 20. medium hor. 9. min. 36. finis hor. 10. min. 45. tota duratio hor. 2. min. 25.

§ 9.

OBSERVATIONS OF HEVELIUS.

The observations of HEVELIUS are found in the *Machina Coelestis*, pars posterior. Owing to the rarity of this work, the observations I have used are given pretty fully. The position of HEVELIUS's observatory, from data kindly communicated by Dr. KAYSER, was

Latitude, $54^\circ\ 21'\ 19''$; $\log \rho \sin \varphi' = 9.90795$.
Longitude, $1^h\ 14^m\ 36^s$ east of Greenwich; $\log \rho \cos \varphi' = 9.76644$.

Eclipsis Solis, 1639. *June* 1.

The times are from a sun-dial ("ex Sciaterico"), which must have been wholly unreliable. I therefore make no use of the observations.*

Page 7.—Observatio Eclipseos Palilicii. Anno 1644, die 15, Novemb. manè instituta Gedani

Initium Occultationis Palilicii accidebat secundum horologium correctum (altitudines enim tum teporis observandi non dabatur occasio) hora 3. matut. 5′. Occultabatur à Lunâ circa 96. grad. limbi, nempe orientalis, ad Montem Alabastrinum Maris Eoi; quo tempore gradus Lunæ 75. limbi. verticalis existebat. Emergebat hor. 4. 5′. 30″. circa gradum 317. limbi occidentalis, Montemq; Alaunum, paululùm supra Paludem Maeotidem; quo temporis articulo gradus limbi Lunæ 78. erat verticalis. Hora 4. 10′ 30″ post emersionem, Palilicium tanto spatio à limbo removebatur, quanto scilicet lata erat Palus Maeotis, parte nimirùm duodecimâ circiter diametri Lunaris.

As the altitudes from which these times are derived are not given, we have to add the uncertainty of the elements of reduction used by HEVELIUS to that of his

* This remark was made at the time of first examining the observations. Afterward, having come into possession of a copy of the original work, I concluded to reduce them, more as an experiment than with the hope of reaching any result of value, and the results are given in a subsequent section.

observations; I have therefore hesitated whether to use the observation, but concluded to do so owing to its early epoch. The equation of time was $-14^{m}\ 51^{s}$, we have, therefore, for the mean times:—

	Immersion.	Emersion.
Apparent times given by HEVELIUS . . .	$15^{h}\ 5^{m}\ 0^{s}$	$16^{h}\ 5^{m}\ 30^{s}$
Mean times thence deduced	$14^{h}\ 50^{m}\ 9^{s}$	$15^{h}\ 50^{m}\ 39^{s}$
Greenwich mean times	$13^{h}\ 35^{m}\ 33^{s}$	$14^{h}\ 36^{m}\ 3^{s}$.

Eclipsis Solis. Anno Aerae Christianae 1645, *die* 21. *Augusti st. n. Gedani observata.*

Crescentis Obscurationis.					Decrescentis Obscurationis.			
Phases.	Secundū accuratū Sciatericū lineae Meridianae applicatum.	Altit. Solis Quad. Orichalc.	Tempus ex altitudinibus correctum.		Phases.			
	h. m. s.	° ′ ″	h. m. s.					
Initium.	11. 23. 45.	. . .	. . .	. .	7½. Dig.	12. 45. 30.	. . .	. . .
½. Dig.	11. 27. 0.	. . .	. . .	. .	7¼.	12. 50. 40.	. . .	. . .
.	11. 31. 30.	47. 15. 0.	11. 31. 6.	. .	7.	12. 54. 45.	. . .	. . .
1½. Dig.	11. 33. 30.	. . .	. . .	. .	6½.	1. 1. 50.	. . .	. . .
2.	11. 38. 0.	. . .	. . .	. .	6.	1. 6. 0.	45. 40. 0.	1. 6. 8.
2½.	11. 42. 30.	. . .	. . .	. .	5¾.	1. 8. 30.	. . .	. . .
3⅛.	11. 45. 30.	. . .	. . .	. .	5¼.	1. 12. 20.	. . .	. . .
4¼.	11. 56. 0.	. . .	. . .	. .	5.	1. 15. 30.	45. 5. 0.	1. 15. 36.
5.	12. 1. 30.	. . .	. . .	. .	4½.	1. 20. 0.	. . .	. . .
5½.	12. 7. 30.	. . .	. . .	. .	4.	1. 23. 45.	44. 20. 0.	1. 24. 25.
6.	12. 11. 30.	. . .	. . .	. .	3.	1. 31. 30.	. . .	. . .
6½.	12. 16. 30.	. . .	. . .	. .	¾.	1. 47. 30.	. . .	. . .
6⅞.	12. 21. 0.	. . .	. . .	. .	½.	1. 49. 0.	. . .	. . .
7.	12. 22. 0.	. . .	. . .	. .	Finis.	1. 53. 0.	. . .	. . .
7⅛.	12. 25. 0.	. . .	. . .	. .	.	1. 56. 0.	41. 55. 0.	1. 55. 50.
7¼.	12. 27. 0.	. . .	. . .	. .	.	2. 26. 0.	38. 46. 0.	2. 26. 40.
7⅜.	12. 30. 0.	. . .	. . .	. .	.	2. 30. 0.	38. 24. 0.	2. 30. 0.
7¼.	12. 31. 0.	. . .	. . .	. .	.	. . .	. . .	. . .
.	12. 36. 30.	47. 0. 0.	12. 37. 13.	. .	.	. . .	. . .	. . .
7¾.	12. 41. 20.	46. 50. 0.	12. 41. 52.	. .	.	. . .	. . .	. . .

The sun's declination at noon being $+11^{\circ}\ 59'.0$, the hour-angles given in the last column seem very nearly correct. The general agreement of the sun-dial with the times deduced from the altitudes affords a strong presumption in favor of the accuracy of both.

The following are the corrections to reduce the sun-dial to mean time, as deduced from the nine individual altitudes:—

$+1^{m}\ 50^{s}$	$5^{m}\ 18^{s}$(?)
$3^{m}\ 30^{s}$	$2^{m}\ 5^{s}$
$3^{m}\ 19^{s}$	$3^{m}\ 21^{s}$
$3^{m}\ 12^{s}$	$2^{m}\ 48^{s}$.
$2^{m}\ 53^{s}$	

In the case of the sixth altitude, there is a discrepancy of two minutes between the times given by HEVELIUS and that deducible from the altitude, which would seem to arise from an error in printing the altitude. This is therefore rejected.

The mean of the eight remaining results is $+ 2^m\ 52^s$, which is the constant applied hereafter to reduce the dial to mean time. The equation of time being $2^m\ 31^s$, the apparent error of the dial is 21^s.

Judging from the discordances, the probable errors of the observed times do not exceed 15^s or 20^s.

Page 8.—Occultatio Palilicii Anno 1645, die 8. Octob. st. n. Lunâ existente gibbâ. Gedani animadversa. Quum Luna Palilicii appropinquaret ad distantiam 15′, ante scilicet conjunctionem, Jovis altitudo Quadrante ex Orichalco confecto, accuratè deprehensa est in plaga Orient, 36° 25′ ∴ $1^h.\ 27^m$.

Principium obscurati Palilicii incidebat in altitudinê Jovis, 38° 48′ ∴ $1^h.\ 43^m$.

Emergente rursùs Palilico ex umbrâ Lunæ, altitudo humeri lucidi Orionis, in plagâ Orient inveniebatur, 38° 45′ ∴ $2^h.\ 57^m$.

The position of Jupiter for the time of immersion has been derived from BOUVARD's tables, with the result:—

Geocentric right ascension	$6^h\ 24^m\ 34^s$
Geocentric declination	$+23°\ 4'.0.$

Hence, from the second altitude, we have, for the local mean time of the immersion, $13^h\ 33^m\ 6^s$. The equation of time is $-12^m\ 25^s$, so that there is a difference of more than two minutes between this reduction and that of HEVELIUS. The discrepancy is the same in the time derived from the first altitude, so that the difference can arise only from the difference of the adopted positions of Jupiter, or other data of reduction.

The altitude of α Orionis gives for local mean time $14^h\ 43^m\ 20^s$, about a minute earlier than that of HEVELIUS. The results of the recomputation of times are:—

Greenwich mean time of immersion . . .	1645, Oct. 7, $12^h\ 18^m\ 30^s$.
Greenwich mean time of emersion . . .	1645, Oct. 7, $13^h\ 28^m\ 44^s$.

Observatio Eclipseos Solaris, Gedani, Anno aerae Christianae 1652, *die* 8 *Aprilis st. n. peracta.*

Ordo Phas. Crescēt.	Phasium Digiti Ecliptici.	Vibrationes perpendiculi.	Verum atq. genuinum tem. ex vibrationibus perp. deductum.	Tempus secundùm exquisitû sciatericum horizontale.	Tempora secū-dùm horologium ambulatorium.	Altitudinès Cētri Solaris.	Accuratum Tempus ex alt. ☉ erutum.
					h. m. s.	gr. m.	
.	.	1.	. . .	. . .	10. 0. 0.	. .	. . . .
.	.	253.	10. 3. 51.	. . .	10. 6. 0.	. .	. . . .
.	.	379.	10. 6. 46.	. . .	10. 9. 0.	. .	. . . .
.	.	507.	10. 9. 44.	. . .	10. 12. 0.	. .	. . . .
.	.	635.	10. 12. 41.	. . .	10. 15. 0.	. .	. . . .
.	.	853.	10. 17. 47.	. . .	10. 20. 0.	. .	. . . .
.	.	1281.	10. 27. 41.	. . .	10. 30. 0.	. .	. . . .
.	.	1985.	10. 43. 55.	. . .	10. 46. 0.	. .	. . . .
.	.	2155.	10. 47. 51.	. . .	10. 50. 0.	. .	. . . .
.	.	2320.	10. 51. 40.	. . .	10. 54. 0.	. .	. . . .
.	.	2484.	10. 55. 25.	. . .	10. 58. 0.	. .	. . . .
.	.	2565.	10. 57. 20.	10. 57. 30.	11. 0. 0.	. .	. . . .
.	.	2598.	10. 58. 8.	10. 58. 0.	11. 0. 45.	. .	. . . .
.	Nihil adh.	2681.	11. 0. 0.	11. 0. 0.	. . .	. .	. . . .
.	Initium.	2826.	11. 3. 21.	11. 3. 30.	11. 6. 12.	. .	. . . .
1.	$2\frac{1}{5}$.dig.	3308.	11. 14. 30.	11. 14. 30.	11. 17. 20.	. .	. . . .
2.	$2\frac{5}{8}$.	3392.	11. 16. 26.	11. 16. 30.	11. 19. 20.	. .	. . . .
3.	$2\frac{3}{4}$.	3503.	11. 19. 0.	11. 19. 0.	11. 21. 18.	. .	. . . .
4.	3.	3574.	11. 20. 39.	11. 21. 0.	11. 23. 58.	. .	. . . .
5.	$3\frac{1}{4}$.ferè.	3657.	11. 22. 34.	11. 23. 0.	11. 25. 53.	. .	. . . .
6.	$3\frac{1}{2}$.& paulò plus.	3750.	11. 24. 43.	11. 25. 0.	11. 28. 26.	. .	. . . .
7.	4.	3838.	11. 26. 45.	11. 27. 0.	11. 30. 29.	. .	. . . .
8.	$4\frac{2}{5}$.	3954.	11. 29. 26.	11. 30. 0.	11. 32. 25.	. .	. . . .
9.	5.	4120.	11. 33. 17.	11. 33. 0.	11. 36. 10.	. .	. . . .
10.	$5\frac{3}{8}$.	4214.	11. 35. 27.	11. 35. 30.	11. 39. 20.	. .	. . . .
11.	$5\frac{3}{4}$.	4270.	11. 36. 45.	11. 37. 0.	11. 40. 0.	. .	. . . .
12.	$6\frac{2}{3}$.	4588.	11. 44. 6.	11. 44. 0.	11. 47. 7.	. .	. . . .
13.	7.	4690.	11. 46. 28.	11. 46. 30.	11. 49. 39.	. .	. . . .
14.	$8\frac{5}{8}$.	5464.	12. 4. 19.	12. 4. 30.	12. 7. 58.	. .	. . . .
15.	9.& paulò plus.	5590.	12. 7. 14.	12. 7. 0.	12. 10. 1.	. .	. . . .
16.	$9\frac{3}{8}$.	5735.	12. 10. 35.	12. 0. 30.	12. 13. 20.	. .	. . . .
			PHASES DECRESCENTES.				
17.	$9\frac{1}{3}$.Dig.	5816.	12. 12. 27.	12. 12. 0.	12. 15. 0.	. .	. . . .
18.	$8\frac{1}{4}$.	6392.	12. 25. 47.	12. 26. 0.	12. 29. 0.	. .	. . . .
19.	$7\frac{7}{8}$.	6488.	12. 28. 0.	12. 28. 30.	12. 31. 21.	. .	. . . .
20.	$6\frac{2}{3}$.	6883.	12. 37. 8.	12. 37. 0.	12. 40. 0.	. .	. . . .
21.	$6\frac{1}{4}$.	7103.	12. 40. 18.	12. 40. 0.	12. 43. 22.	. .	. . . .
22.	$4\frac{3}{4}$.	7402.	12. 49. 8.	12. 49. 0.	12. 53. 0.	. .	. . . .
.	$4\frac{1}{4}$.	7494.	12. 51. 6.	12. 51. 0.	12. 54. 31.	. .	. . . .
23.	$4\frac{1}{5}$.	7558.	12. 52. 45.	12. 52. 30.	12. 56. 11.	. .	. . . .
24.	1.circ.	8444.	1. 13. 15.	1. 12. 30.	1. 16. 40.	. .	. . . .
25.	$\frac{3}{4}$.	8514.	1. 14. 51.	1. 15. 0.	1. 19. 21.	. .	. . . .
26.	$\frac{3}{8}$.	8575.	1. 16. 17.	1. 16. 30.	1. 20. 45.	. .	. . . .
.	Finis.	8694.	1. 19. 2.	1. 19. 0.	1. 23. 0.	. .	. . . .

Observatio Eclipseos Solaris, Gedani, Anno aerae Christianae 1652, *die* 8 *Aprilis st. n. peracta*—Continued.

Ordo Phas. Crescēt.	Phasium Digiti Ecliptici.	Vibrationes perpendiculi.	Verum atq. genuinum tem. ex vibrationibus perp. deductum.	Tempus secundùm exquisitû sciatericum horizontale.	Tempora secūdùm horologium ambulatorium.	Altitudinès Cêtri Solaris.	Accuratum Tempus ex alt. ☉ erutum.
					h. m. s.	gr. m.	
.	.	9096.	1. 28. 19.	1. 29. 0.	1. 33. 0.	39. 50.	1. 29. 22.
.	.	9244.	1. 31. 45.	1. 32. 0.	1. 36. 5.	39. 32.	1. 33. 29.
.	.	9454.	1. 36. 36.	1. 37. 0.	1. 41. 0.	39. 10.	1. 38. 19.
.	.	10664.	2. 4. 35.	2. 5. 0.	2. 8. 47.	. .	. . .
.	.	. .	. . .	2. 19. 30.	2. 23. 20.	. .	. . .
.	.	. .	. . .	2. 21. 0.	2. 24. 52.	. .	. . .
.	.	. .	. . .	. . .	2. 25. 47.	35. 13.	2. 22 5.
.	.	11461.	2. 23. 0.	2. 23. 0.	2. 27. 0.	35. 3.	2. 23. 39.
.	.	. .	. . .	2. 24. c.	2. 28. 0.	. .	. . .
.	.	. .	. . .	. . .	2. 29. 0.	34. 44.	2. 25. 14.
.	.	. .	. . .	2. 29. 0.	. . .	34. 37.	2. 28. 10.
.	.	. .	. . .	. . .	2. 32. 30.	34. 27.	2. 29. 16.
.	.	. .	. . .	2. 33. 0.	. . .	34. 9.	2. 32. 0.
.	.	. .	. . .	2. 36. 0.	. . .	33. 50.	2. 35. 0.
.	.	. .	. . .	. . .	4. 48. 15.	17. 4.	4. 45. 9.
.	.	. .	. . .	. . .	4. 50. 15.	16. 50.	4. 46. 51.
.	.	. .	. . .	4. 49. 0.	4. 53. 0.	. .	. . .
.	.	. .	. . .	4. 57. 0.	5. 1. 0.	. .	. . .
.	.	. .	. . .	5. 3. 0.	5. 6. 45.	14. 30.	5. 3. 4.
.	.	. .	. . .	5. 6. 0.	5. 10. 20.	. .	. . .

Animadvertenda.

Cum coelum, ab ipso diluculo matutino, nubibus undiquè ita esset obductum, ut horologium artificiale, tam singula minuta secunda, quam dena tertia accuratè commonstrans, neque ad altitudines Solares, neque ad Sciatericum dingi atq; corrigi posse, ulla spes superesset; consultum esse duximus, hora statim 10, tum majoris evidentiae gratiâ, tum ut eò certuis constaret, quot earum horam adimplerent integram, perpendiculi annotare vibrationes. Animadversum autem sic fuit, tam ex Sciaterico nostro singula minuta indicante, atque ad lineam meridianam fideliter applicato, quam ex altitudinibus Solaribus, 2595 oscillationes conficere horam integram, & 43¼ minutum primum; tot planè scilicet, quot ante biennium, circa Eclipsin Solarem, in simili temporis intervallo ejusdem perpendiculi ope deprehendimus.

Instante igitur initio Eclipseos, praeter ferè omnem spem, Sol adspectu suo nos exhilaravit admodum; sic ut horâ 11 secundùm Horologium ambulatorium, & Sciatericum, & Vibrationes perpendiculi, exquisitè simul conjugere octatq; conferre facultas daretur, Sole interim tum temporis prorsùs existente puro, & à Lunâ illaeso. Post initium verò quod accuratissimè annotatum, Sol iterum sub nubibus aliquantulùm delituit; quamquam postmodum per intervalla satis temporis nobis consessum fuerit multas diversissimasq; (attestante observationis inconismo) & quidem beneficio limitatioris Telescopii, in camerâ obscuratâ, per Machinam, in Selenographia nostrâ p. 98 descriptam, ritè & fideliter annotare.

Quod autem in ipso Eclipseos principio altitudines Solares non fuerint à nobis capta, causa hoc est: quod in tali Solis circa meridiem situ, parum iis admodum sit fidendum. Quocirca altitudines circa exordium rejecimus, usque dum Sol à meridiano moveretur longius; atque tum demum aliquot fuerunt notatae, ad majorem scilicet observationis fidem. Quae omnes, ut cum sciaterico & perpendiculi reciprocationibus quàm optimè conveniunt; sic simul cum sciaterico & oscillationibus indicant, in quantùm horologium nostrū mechanicum, tam circa initium, quam finem, à vero aberraverit tempore; ob quam tamen deviationem horologium istud non est planè contemnendum Inde namque verum atque exactum tempus, aeque ut ex sciaterico & altitudinibus, excessu tantum, vel defectu probè attento, elicitur: imo denegatis interdum, ob coelū subnubilum, altitudinibus, & interruptâ adulteratâq; Solis in sciaterico umbrâ, ejusmodi automata in observationibus coelestibus summoperè sunt necessaria.

Caeterum nolui omninò circa phases delinendas, (ut ut plerumque istud fieri solet) non tantum integros eligere digitos. semidigitosque; sed quascunq; designavi, quae se se commode offerebant, & quas tutò, & exquisitè acquirere me posse praevidebam, spretis reliquis omnibus. Quippe ob leve etiam impedimentum, & ob motum Solis velocissimum, haec vel illa phasis, licet maxime eam attendamus, facilè nonnunquam praeterlabitur.

Adhaec phases ipsas, in adjecta figurâ I. aliter planè, quam in Observatione Anno 1649 habitâ, nimirum cum ipsis inclinationibus, uti in Tabellâ cameraque obscuratâ sunt observatae, ómnes tamen sub uno eodemque perpendiculo, depinximus.

Proinde constat, Solem circa initium in 77 gradu à puncto Nadir, Africam versùs, hora scilicet 11.3′.21″ fuisse obscuratum; atque circa 25 circiter gradum à puncto Zenith, Aquilonem versùs, hora videlicet 1.19′.0″ desiisse obscurari. Medium verò, sive maxima obscuratio hujus deliquii, incidit circa phasin nostram 16, hora scilicet 12.10′ 35″, id quod pariter ex diversissimus faciebus inter se collatis satis certè patet. Vera itaque ejus magnitudo 9⅜ digitorum, sive 9 digit. & 23′ hic Dantisci exstitit. Ratio autem semidiametrorum Solis & Lunae inventa fuit hâc vice, ut 1000 ad 1033 circit.

Quomodo praetereà in Eclipseos progressu phasium cornua se se praebuerint conspicienda, & quem limbi gradum in omni positu tetigerint, ipsum Schema deliquii cuique haud currente oculo id perlustraturo, sufficienter ostendet. Quò verò adhuc clariùs hanc Eclipsin ponerem ob oculos, operae duxi precium, praecipuas etiam phases, tam crescentes, quàm decrescentes, cum earum inclinationibus, ex majore Schemate deductas, & ad integros digitos proportionatas, in forma representare minori; id quod nemini forsitam accidet ingratum.

No altitudes having been observed until the eclipse was entirely over, there is necessarily some little doubt respecting the correction to the pendulum and the sun-

dial. Recomputing some of the altitudes, I find hour-angles averaging 25^s greater than those of HEVELIUS. The corrections to the dial derived from the first altitudes are decidedly positive, while the later ones do not indicate any correction. The general result agrees with the observations of 1645 in indicating a positive correction to the apparent time of the sun-dial, a correction which we may estimate at $+25^s \pm 10^s$. The equation of time being $+1^m\ 37^s$, the entire correction to reduce to local mean time will be $+2^m\ 2^s$. This correction is to be applied to the mean of the results, "ex vibrationibus perpendiculi", and "secundum sciatericum".

Page 35.—*Eclipse of* 1654, *August* 12*th.*

The times do not seem entirely reliable unless they are founded on more data than are given. The clock seems to have been corrected by a single altitude of the sun. The following are all the results it seems worth while to use. The second column is headed "Horolog. artificiale ex altit. perpêd. correctum"; the third, "Vibrationes perpendiculi":—

	H. M. S.		
.	8. 0. 0.	0.	
.	8. 19. 3.	743.	
.	9. 0. 0.	2340.	
Initium.	9. 25. 15.	3322.	
¼. Dig.	9. 26. 30.	3371.	
1. Dig.	9. 31. 0.	3548.	
2½. & paulò plus.	9. 41. 40.	3964.	
3. ferè.	9. 42. 58.	4015.	
3½. ferè.	9. 46. 45.	4162.	
.	9. 47. 8.	4178.	☉ cent. alt. $=42°.\ 53'.\ 0''.$; $t=9^h.\ 47^m.\ 8^s.$
3¾.	9. 48. 22.	4227.	☉ azimuth $=46°.\ 18'.$; $t=9^h.\ 47^m.\ 3^s.$
4.	9. 49. 0.	4289.	

The times in the second column are deduced from the "vibrationes perpendiculi" in the last by assuming 39 vib. = 1 min., and correcting the count by the altitude. But in the last there is an error either of one minute or of forty vibrations: it is hard to tell which. I deduce the apparent time, $9^h\ 46^m\ 55^s$, from the altitude, 13^s less than that of HEVELIUS.

Page 45.—*Observatio Eclipseos Solaris. Gedani. Anno 1656, die 26 Januar. habita.*

Quantitas Phasium observat.	Oscillationes perpendiculi.	Tempus ex Oscillationibus erutum.	Altitudines Centri Solaris Quad. Azimut. captae.	Azimutha ⊙ occident.	Tempus ex Altitudinibus ⊙ supputatum.	Tempus ex Azimuthis deductum.	Tempus secundū horologium ambulatorium.
			° ′ ″	° ′	h. m. s.	h. m. s.	h. m. s.
.	.	. . .	16. 57. 15.	0. 0.	12. 0. 0.	12. 0. 0.	12. 0. 0.
.	.	. . .	15. 27. 15.	16. 56.	1. 10. 12.	1. 9. 0.	1. 9. 10.
.	0.	1. 30. 0.	. . .	. .	. . .	. . .	1. 30. 0.
.	587.	1. 44. 55.	. . .	. .	. . .	. . .	1. 45. 0.
Initium.	827.	1. 51. 2.	. . .	. .	. . .	. . .	1. 51. 12.
$\frac{7}{12}$. dig.	1000.	1. 55. 25.	. . .	. .	. . .	. . .	1. 55. 35.
$\frac{11}{12}$.	1096.	1. 57. 22.	. . .	. .	. . .	. . .	1. 57. 32.
1.	1170.	1. 59. 50.	. . .	. .	. . .	. . .	2. 0. 0.
$1\frac{1}{4}$. ferè.	1282.	2. 2. 33.	. . .	. .	. . .	. . .	2. 2. 49.
$1\frac{3}{4}$. ferè.	1495.	2. 8. 0.	. . .	. .	. . .	. . .	2. 7. 45.
.	1639.	2. 11. 40.	11. 46. 0.	31. 34.	2. 12. 0.	2. 11. 22.	2. 11. 29.
$2\frac{3}{4}$.	1745.	2. 14. 22.	11. 33. 0.	32. 17.	2. 14. 42.	2. 14. 0.	2. 14. 18.
Paulò plus.	1811.	2. 16. 3.	. . .	. .	. . .	. . .	2. 15. 54.
3. dig.	1860.	2. 17. 17.	. . .	. .	. . .	. . .	2. 16. 56.
.	1961.	2. 19. 51.	11. 8. 0.	33. 33.	2. 19. 48.	2. 19. 45.	2. 19. 46.
$3\frac{1}{2}$.	2029.	2. 21. 35.	. . .	. .	. . .	. . .	2. 21. 29.
$3\frac{3}{4}$.	2110.	2. 23. 49.	. . .	. .	. . .	. . .	2. 23. 32.
4.	2213.	2. 26. 16.	10. 37. 30.	35. 0.	2. 26. 21.	2. 26. 10.	2. 26. 15.
$4\frac{1}{8}$.	2302.	2. 28. 31.	. . .	. .	. . .	. . .	2. 28. 34.
.	2400.	2. 31. 1.	10. 13. 0.	36. 7.	2. 31. 7.	2. 31. 8.	2. 31. 5.
$4\frac{1}{2}$. & paulò ampl.	2478.	2. 33. 0.	10. 4. 0.	36. 28.	2. 32. 50.	2. 32. 42.	2. 32. 58.
5.	2589.	2. 35. 49.	. . .	. .	. . .	. . .	2. 35. 59.
.	2595.	2. 36. 0.	9. 48. 0.	37. 12.	2. 35. 54.	2. 35. 58.	2. 36. 3.
$5\frac{1}{8}$.	2676.	2. 38. 2.	9. 36. 0.	37. 36.	2. 38. 10.	2. 37. 47.	2. 38. 5.
$5\frac{3}{8}$.	2766.	2. 40. 20.	. . .	. .	. . .	. . .	2. 40. 24.
.	2814.	2. 41. 33.	9. 20. 0.	38. 24.	2. 41. 15.	2. 41. 21.	2. 41. 38.
$5\frac{5}{8}$.	2820.	2. 41. 42.	. . .	. .	. . .	. . .	2. 41. 49.
.	2898.	2. 43. 40.	9. 7. 30.	38. 54.	2. 43. 32.	2. 43. 37.	2. 43. 50.
6.	3004.	2. 46. 22.	8. 52. 30.	39. 31.	2. 46. 14.	2. 46. 24.	2. 46. 35.
$6\frac{3}{8}$.	3325.	2. 54. 33.	8. 8. 0.	41. 18.	2. 54. 19.	2. 54. 32.	2. 54. 58.
$6\frac{5}{8}$.	3469.	2. 58. 7.	7. 47. 30.	42. 6.	2. 57. 53.	2. 58. 11.	2. 58. 38.
$6\frac{7}{8}$.	3598.	3. 1. 28.	7. 28. 0.	42. 39.	3. 0. 25.	3. 0. 45.	3. 1. 53.
7. frerè.	3711.	3. 4. 21.	7. 12. 0.	43. 23.	3. 4. 6.	3. 4. 6.	3. 4. 41.
.	3913.	3. 9. 29.	6. 42. 0.	44. 30.	3. 9. 5.	3. 9. 16.	3. 9. 51.
7. & paulò minus.	4055.	3. 13. 6.	6. 18. 0.	45. 18.	3. 13. 1.	3. 13. 1.	3. 13. 40.
$6\frac{11}{12}$.	4077.	3. 13. 30.	. . .	. .	. . .	. . .	3. 14. 12.
$6\frac{7}{8}$.	4578.	3. 16. 23.	5. 59. 0.	46. 0.	3. 16. 6.	3. 16. 17.	3. 16. 46.
$6\frac{3}{4}$.	4734.	3. 20. 21.	5. 33. 0.	46. 49.	3. 20. 16.	3. 20. 8.	3. 20. 43.
.	5136.	3. 30. 35.	. . .	. .	. . .	. . .	3. 31. 0.

HEVELIUS states that his pendulum made 2360 vibrations in an hour. The equation of time is $+13^{m}\ 20^{s}$, and this has been taken as the correction applicable to the times in the third column. But, as scarcely more than half the eclipse was observed,

there is no way of eliminating the systematic errors of observation. The observations are therefore of no great value.

Page 49 —*Occultatio Stellulae in Ariete.*

Anno 1656, die, ☿, 1 Martii vesperi, duas Stellulas, sed globo hactenus nondum adscriptas à Luna plusquàm Lunatâ tectas observavi; prior *a* supra eductionem caudae Arietis sita est, ad 17′ vel 18′ Boream versùs; *s* in longitudine vero ad 11′ promotior est, quàm dicta Stella cognita. Tegebatur autem à Lunâ, alto Palilicio 38° 13′ 30″.

The mean time deducible from this altitude is . . . . . $8^h\ 34^m\ 45^s$
Greenwich time . . . . $7^h\ 20^m\ 9^s$.

Page 89.—*Observatio Occultationis Binarum Stellularum in* ♉ 1658 *Oct.* 14. *vesperi.*

Stella una fuit sequens duarum Australior in Collo ♉, cujus longitudo 1° 18′ ♊. Latitudo B. 0° 46′. Stella altera non habetur in Catalogo aut globis: Erat autem paulo Orientalior priore & Borealior, quam rursus sequebantur duae aliae Stellae, tanto intervallo, ut omnes simul Tubo caperentur.

Tempus juxta. Horolog. majus.	Alt. Capella.	Tempus ex Altitud.	
9. 23. 46.	34. 45.	9. 25. 48.	
9. 37. 10.	36. 25.	9. 39. 4.	Hinc propter intervenientes nubes & pluvias Luna & Ingressus Stellae sub Lunam videri non potuit.
10. 8. 0.	. .	. . .	Stella incognita paulò minus distabat à Luna diametro Lunari: & paulò plus quā duae Stellulae eandem sequentes à se invicē.
11. 5. 15.	49. 28.	11. 16. 28.	
11. 20. 0.	. .	11. 21. 15.	Ingressa videbatur Stella discum Lunarem supra Montē Alabastr.
. . .	. .	. . .	Stella incognita non amplius conspicua, videbatur subiisse discum Lunarem.

The following are the mean times actually resulting from the three altitudes of Capella, together with the corrections to the apparent times of Hevelius, and the computed clock-corrections:—

Mean Times.	Diff. from Hevelius.	Clock-correction.
h m s	*m s*	*m s*
9 11 34	— 14 14	— 12 12
9 24 50	— 14 14	— 12 20
11 1 39	— 14 58	— 13 36

The equation of time is actually $14^m\ 3^s$. The first two altitudes agree well enough with this. But, in the case of the last, there is clearly an error of about ten minutes in printing the clock-time: it may be assumed that the minutes should be 15 instead of 5. But there is still a discrepancy of more than a minute between the correction from this and from the first two altitudes. A change of 5′ in the altitude will reduce the difference from Hevelius to $14^m\ 23^s$, and the clock-correction to $13^m\ 1^s$. The mean of this, and of that computed from the altitude as given, is $13^m\ 18^s$, which I shall accept as the most probable result of the altitude. The first two altitudes give a result 1^m less.

Notwithstanding the lapse of two hours, I consider them entitled to some little weight in the result, and shall, therefore, adopt the clock-correction $13^m\ 5^s$, which gives for the time of occultation $11^h\ 6^m\ 55^s$.

The probable error of clock-correction may be estimated at 30^s, and that of the observed clock-time at 15^s. We then have, for the Greenwich mean time of the occultation,

$$9^h\ 52^m\ 19^s \pm 35^s.$$

To this probable error of time is to be added the uncertainty whether the actual occultation was really seen, as it must have taken place at the bright limb.

Page 217.—*Occultatio Clarae Boreal in fronte Scorpii*, 1660, 27 *Apr. manè.*

	h m s		° ′ ″		
Horolog.	1. 32. 57.	Alt. Spica	16. 43. 0.	Temp. ex altitu.	1. 38. 15.
	1. 49. 35.	" Arcturi	47. 58. 0.		1. 54. 3.
	1. 50. 10.	" "	47. 52. 0.		1. 54. 56.
	2. 34. 30.	Exitus Stella.	Optime conspeximus.		2. 39. 0.
	3. 30. 30.	Alt. Arct.	34. 42. 0.		3. 35. 34.
	3. 36. 15.		33. 46. 0.		3. 42. 7.
	3. 38. 35.		33. 29. 0.		3. 44. 6.

The clock-corrections resulting from these altitudes are:—

$$\begin{aligned}
&(1) + 4^m\ 42^s \\
&(2) + 3^m\ 31^s \\
&(3) + 3^m\ 48^s \\
&(4) + 3^m\ 50^s \\
&(5) + 4^m\ 36^s \\
&(6) + 4^m\ 15^s.
\end{aligned}$$

The resulting mean clock-correction is $+ 4^m\ 7^s$, and the probable error of both clocks and observations about 8^s. The Greenwich mean time of the occultation is therefore $13^h\ 24^m\ 1^s \pm 12^s$.

Page 235.—*Occultatio Spicae Virginis*, 1660. *die Jovis*, 17 *Juni. vesp.*

Horolog. *h. m. s.*		Altitudines. ° ′ ″	Tempus ex altitud. ° ′ ″	
9. 51. 10.	Arcturi . .	51. 38.* 0.	9. 53. 10.	
9. 56. 15.	Spicae . .	18. 2. 0.	9. 59. 29.	
10. 0. 0.	Marg. ☾ Sup.	18. 8. 0.	10. 2. 15.	
10. 33. 35.	Arcturi . .	47. 5. 0.	10. 36. 10.	
10. 37. 20.	Marg. ☾. sup.	14. 0. 0.	10. 39. 30.	
10. 54. 0.			10. 56. 0.	Obtegebatur Spica, ♍ a Lunâ circa parte sc. obscuram.
11. 32. 20.	Arcturi . .	39. 45. 0.	11. 33. 33.	
11. 39. 10.			11. 41. 30.	Adhuc post Lunam latebat Spica.

Animadvertenda.

Postmodum nubes Lunam coelumque tegebant, ut nihil amplius de exitu Spicae deprehendere potuerimus.

The following are the results of the altitudes of stars:—

Clock Times.	Computed Mean Times.	Diff. from HEVELIUS.	Clock-correction.
h m s	h m s	m s	m s
9 51 10	9 53 21	+ 0 11	+ 2 11
9 56 15	9 59 57	+ 0 28	+ 3 42
10 33 35	10 36 19	+ 0 9	+ 2 44
11 32 20	11 33 41	+ 0 8	+ 1 21

The mean of the four clock-corrections is $+2^m\ 30^s \pm 12^s$. But the small correction resulting from the last altitude gives rise to at least a suspicion of a large clock-rate. The rate deduced from the observations by least squares is $-0^s.88$ per minute, and the correction at the time of occultation will become $+2^m\ 7^s$. But the existence of so large a rate seems quite improbable. I shall therefore adopt $+2^m\ 25^s \pm 13^s$ as the most probable correction at the moment of occultation. This will give for the local mean time $10^h\ 56^m\ 25^s$, and

$$9^h\ 41^m\ 49^s \pm 20^s$$

as the probable Greenwich time of the occultation.

Page 301.—*Eclipsis Solaris, Anno* 1661, *die* 30. *Martii.*

Quantitas Phasium Observata.	Horologium Ambulatorium.	Horologium perpendiculi.	Altitudines Solis.	Tempus correctum.	Animadventenda. Amb. Clock Corr. M. T.
.	9. 1. 21.	9. 1. 21.	28. 23. 0.	9. 3. 9.	+ 7^{m}. 15^{s}.
.	9. 2. 35.	9. 2. 36.	28. 35. 0.	9. 4. 54.	7 43
.	9. 10. 29.	9. 10. 10.	29. 29. 0.	9. 12. 58.	dub. 7 49
.	9. 45. 35.	9. 45. 13.	33. 0. 0.	9. 47. 23.	+ 7 2
Initium.	10. 12. 3.	10. 11. 41.	. . .	10. 13. 15.	Initium circa 117° à puncto Zenith contigit.
$\frac{1}{4}$. Dig.	10. 13. 25.	10. 13. 5.	. . .	10. 14. 37.	
$\frac{3}{8}$.	10. 13. 53.	10. 13. 33.	. . .	10. 15. 4.	
$\frac{5}{8}$.	10. 15. 42.	10. 15. 24.	. . .	10. 16. 56.	
$\frac{7}{8}$.	10. 17. 8.	10. 16. 52.	. . .	10. 18. 22.	
1 d. & amplius.	10. 18. 31.	10. 18. 15.	. . .	10. 19. 44.	
$1\frac{3}{8}$. ferè.	10. 20. 15.	10. 19. 58.	. . .	10. 21. 27.	
$1\frac{3}{4}$.	10. 23. 17.	10. 23. 0.	. . .	10. 24. 27.	
$3\frac{1}{4}$.	10. 34. 24.	10. 34. 10.	. . .	10. 35. 31.	
$4\frac{3}{8}$.	10. 43. 11.	10. 43. 5.	. . .	10. 44. 20.	
$5\frac{5}{8}$.	10. 51. 53.	10. 51. 48.	. . .	10. 52. 58.	
$5\frac{7}{8}$.	10. 52. 49.	10. 52. 45.	. . .	10. 53. 54.	
6 d. & amp.	10. 54. 36.	10. 54. 31.	. . .	10. 55. 40.	Portio circuli Lunaris per centrum Solis transiens, vel obscurata pars Solis, hora 10. 55′ continebat in Limbo Solari 122°.
$6\frac{3}{8}$.	10. 55. 31.	10. 55. 26.	. . .	10. 56. 34.	
$6\frac{5}{8}$.	10. 57. 26.	10. 57. 23.	. . .	10. 58. 29.	
7. circiter.	11. 1. 56.	11. 1. 55.	. . .	11. 3. 0.	
7. paulò plus.	11. 5. 6.	11. 5. 0.	. . .	11. 6. 4.	Ratio Diametri ⊙ ad Diamet. ☾. observat, est ut 1000 ad 1105. Data igitur semid. ⊙ ex meis observatis 15′ 54″ provenit semid. ☽ in hac Eclipsis 16′ 24″.
$7\frac{1}{8}$. circi.	11. 6. 19.	11. 6. 15	. . .	11. 7. 17.	
$7\frac{5}{8}$.	11. 12. 10.	11. 12. 11.	. . .	11. 13. 8.	
$7\frac{3}{4}$.	11. 14. 15.	11. 14. 14.	. . .	11. 15. 9.	
$7\frac{1}{8}$.	11. 33. 44.	11. 33. 41.	. . .	11. 34. 34.	Max. obsc. 11. 20.
6^{1}. ferè.	11. 46. 54.	11. 56. 50.	. . .	. . .	
$4\frac{1}{2}$. ferè.	11. 57. 47.	11. 57. 45.	. . .	. . .	
$4\frac{1}{8}$.	11. 59. 36.	11. 59 31.	. . .	. . .	
$3\frac{3}{4}$.	12. 1. 20.	12. 1. 19.	. . .	. . .	
$2\frac{3}{4}$.	12. 8. 25.	12. 8. 20.	. . .	. . .	
$2\frac{5}{8}$.	12. 9. 32.	12. 9. 28.	. . .	. . .	
$2\frac{1}{2}$. fer.	12. 11. 0.	12. 11. 0.	. . .	. . .	
$2\frac{1}{4}$.	12. 12. 15.	12. 12. 15.	. . .	. . .	
$2\frac{1}{8}$.	. . .	12. 13. 0.	. . .	. . .	
2. paulò plus.	12. 13. 45.	12. 13. 45.	. . .	. . .	
$1\frac{7}{8}$. ferè.	12. 15. 15.	12. 15. 15.	. . .	. . .	
$1\frac{3}{4}$.	12. 16. 10.	12. 16. 10.	. . .	. . .	
$1\frac{5}{8}$.	12. 17. 0.	12. 17. 0.	. . .	. . .	
$1\frac{1}{2}$. ferè.	12. 18. 20.	12. 18. 17.	. . .	. . .	
$1\frac{1}{4}$.	12. 19. 20.	12. 19. 19.	. . .	. . .	
$1\frac{1}{8}$.	12. 19. 57.	12. 19. 57.	. . .	. . .	
1. ferè.	12. 21. 9.	12. 21. 9.	. . .	. . .	
$\frac{3}{4}$.	12. 22. 8.	12. 22. 8.	. . .	. . .	
$\frac{1}{2}$.	12. 23. 34.	12. 23. 34.	. . .	. . .	
.	. . .	. . .	39. 21. 40.	12. 26. 17.	
Finis.	12. 26. 39.	12. 26. 40.	. . .	12. 27. 3.	Finis circa 81° à puncto Zenith. occidit.
.	12. 51. 55.	dub.	38. 33. 20.	12. 51. 46.	+ 2′ 2″ + 6 18
.	12. 57. 49.	. . .	38. 16. 35.	12. 58. 6.	1 57 6 39
.	12. 58. 49.	. . .	38. 13. 25.	12. 59. 14.	1 52 6 42
.	1. 0. 35.	. . .	38. 7. 30.	1. 1. 17.	1 47 6 54.

Animadvertenda.

Instante hâc Eclipsi Solis, omnem ad hibuimus operam, ut cùm longè ex optatissimo nostro hospite Dn Ismaeli Bullialdo, omnia illa, quae ad eclipsin observandam spectare arbitrabar, essent in promtu; imprimus, duas cameras obscuratas adornavi, alteram pro Majoribus, alteram pro Minoribus, qui in magnâ aderant frequentiâ, et quidem eâ ratione, quâ videbantur commodiores. Multo manè die 30 Martii, oriente Sole, quamquam Coelum undiqùe erat serenum, sub horam tamen octavam nubibus satis obscuris obduci coepit, adeo ut Solem Quadrante, nec Majori, nec Minori nostro aeneo rimari potuerimus. Horâ verò 9, aër pabulùm attenuabatur, ut satis accuratè altitudines Solares caperentur: quo tempore Horologium tam perpendiculare, quam usitatum ambulatorium, unâ cum Sciaterico in minutis distributo, praecisè admodum conveniebat.

Hora 9. 30′, Cameram ingressi sumus oculos defixos omnino in Tabulâ observatoriâ, praesentibus praecipuis Nostrae Urbis Luminibus, tenentes, ne nobis initium, quod instare judicabam, elaberetur. Huic nostro proposito Coelum tum clarâ etiam facie annuit, sic ut ipsum Lunae sub Solem ingressum, punctumque attactus dilucide admodum conspiceretur, in 117° à puncto verticali, occasum versùs; & quidem primùm à Praeclarissimo Bullialdo minime otiosum se praebente spectatorem.

* * * * Semidiametrum Lunae notabiliter minorem esse, in hoc deliquio, quàm quidem Calculus promiserat; quae in peculiari chartâ, ex tribus in peripheriâ Lunae, à tribus diversis observationibus, simul notatis punctis, multoties explorata est.

* * * phasin tamen istam maximam accuratè obtinuimus: 7¾ digit. nempè haud fuisse majorem. * * *.

Hora 12 26′ 17″ alto Sole 39° 21′ 40″. Quadrante Azimuthali nostro, in alterâ satis longè dissita speculâ nostrâ constituto, alius Observator, harum rerum alias bene gnarus, finem Eclipsis in pinnacidio Quadrantis, per nudum foramen deprehendit.

Quod etsi cum nostro, ope Telescopii, in Camerâ obscuratâ, annotato finè, in upsis secundis non conveniat (nec sane adeo occuratè istâ ratione unquam fieri potest.) tamen lubens etiam hanc Observationem apponere volui; quò videas in ista minùs accuratâ observatione, non nisi 46″ aberratum esse: quod profectò nullius est momenti, * * * *.

Rejecting the altitudes within half an hour of noon, the eight others give the following clock-corrections:—

Hor. amb.			Corr. to Hor. amb.		Corr. to Hor. perp.	
h	*m*	*s*	*m*	*s*	*m*	*s*
9	1	21	+ 7	15	+ 7	15
	2	35	7	43	7	42
	10	29	7	49	7	68
	45	35	7	2	7	24
12	51	55	+ 6	18	.	.
	57	49	6	39	.	.
	58	49	6	42	.	.
	60	35	6	54	.	.

Taking the means, we have:—

At $9^h.25$, corr. Hor. amb. $+ 7^m\ 27^s$; corr. Hor. p. $+ 7^m\ 38^s$.
At $12^h.93$, corr. Hor. amb. $+ 6^m\ 38^s$; corr. Hor. p. $+ 6^m\ 38^s$. (?)

These corrections being interpolated to the times of observation, the mean result from the two clocks is taken as the local mean time.

Page 330.—*Occultatio Saturni*, 1661. 3 *Augusti Vesp. st. n.*

There is only a single column of times, which is headed "Tempus ex horolog; aestimat simul correctum". I am therefore in doubt how the observations were made. The following extracts are all that can be of any use:—

Tempus ex &c:—

7. 58. 0.	♄ Limb. ☽ stringebat.		
7. 58. 20.	Verum initium occult. Subivit dimidio copore quantum conjicere licuit.		
7. 59. 50.	Tertia pars adhuc videri potuit.		
8. 0. 25.	Saturnus totus occultat.		
8. 6. 30.	Alt. ☽ limb. sup. 16° 22′ circ.		
9. 3. 35.	Initium emersionis.		
9. 4. 0.	Jam major particula de ♄ apparuit.		
9. 4. 10.	Finis occultationis. Mediū ♄ corp. visū.		
9. 4. 35.	Nondū totus cōspect.		
9. 4. 45.	Finis totalis emersionis.		
			° ′ ″
9. 50. 53.	Altit. Arcturi		27. 31. 0.
9. 54. 36.	"	Scheat Pegasi	38. 53. 0.
9. 57. 44.	"	" "	39. 20. 0.
11. 1. 36.	"	Schedir. Cassiop.	53. 13. 0.
11. 7. 7.	"	Capella	17. 56. 0.
11. 8. 46.			18. 4. 0.
11. 11. 30.			18. 17. 0.

Besides having to take the times entirely on credit, these observations are subject to other sources of doubt. That Saturn should have appeared half-covered, "quantum conjicere licuit", twenty seconds after it touched the moon, while one third was still visible a minute and a half longer, is something difficult to accept, even making all allowance for uncertainty of observation, and leads to a suspicion of an error of a minute in the second time.

Page 419.—*Occultatio trium Stellularum in Capite Tauri* 1663, 14 *Mar. vesperi.* Stellula inferior A quartae magnitudinis, cujus longitudo est 1° 54′ ♊ & Lat. 5° 33′ Aust. * * St. B. Austral. sequentium.

Tempus sec. hor. amb.

H. M. S.		
8. 53. 30.	Initium occultationis, ✻ A.	
8. 55. 0.	Altitudo Arcturi	27°. 3′.
9. 42. 0.	" "	34. 12.
9. 44. 0.	Principium occultationis, ✻ B.	
9. 47. 0.	Initium occultationis, ✻ C.	
9. 52. 30.	Altitudo Arcturi	35°. 42′.

The clock-corrections given by the three altitudes are:—

$$(1)\ +45^{m}\ 45^{s}$$
$$(2)\ +48^{m}\ \ 5^{s}$$
$$(3)\ +48^{m}\ 10^{s}.$$

The clock-corrections I shall adopt are, for the first occultation, $+45^{m}\ 55^{s}$; and, for the two others, $+48^{m}\ 7^{s}$. The Greenwich mean times of the occultations will then be:—

Star A (71 Tauri)	$8^{h}\ 24^{m}\ 49^{s} \pm 40^{s}$
Star B (θ_1 or θ_2 Tauri)	$9^{h}\ 17^{m}\ 31^{s} \pm 25^{s}$
Star C (θ_2 or θ_1 Tauri)	$9^{h}\ 20^{m}\ 31^{s} \pm 25^{s}$.

Page 423.—1663, *Aug.* 18. *Occultation of a star during lunar eclipse.*

Horol. amb.		° ′	Temp. corr.
8. 51. 28.	Alt. Arcturi . . .	27. 58.	8. 52. 52.
8. 53. 53.	" " . . .	27. 39.	8. 55. 3.
9. 11. 36.	Stella jam occultata. . .		9. 13. 0.
9. 42. 43.	Alt. Lucidae Coronae.	37. 31.	9. 43. 35.
9. 44. 48.	" " "	37. 12.	9. 45. 45.
9. 46. 36.	☽ Limbi superioris.	16. 54.	9. 47. 36.
10. 1. 30.	Stella rursus prodiit . .		10. 2. 30.
11. 14. 37.	Alt. Lyrae, . . .	58. 37.	11. 15. 11.
11. 18. 4.	. . . .	58. 11.	11. 19. 2.
11. 19. 40.	. . . .	57. 45.	11. 21. 17.
12. 8. 46.	. . . .	50. 39.	12. 10. 3.
12. 10. 25.	. . . .	50. 26.	12. 11. 39.

The results of the altitudes of stars are:—

Mean Times.	Diff. from HEVELIUS.	Clock-correction.
h *m* *s*	*m* *s*	*m* *s*
8 55 40	+ 2 48	+ 4 12
8 57 50	+ 2 47	+ 3 57
9 46 30	+ 2 55	+ 3 47
9 48 40	+ 2 55	+ 3 52
11 17 54	+ 2 43	+ 3 17
11 21 3	+ 2 1	(+ 2 59)
11 24 12	+ 2 55	+ 4 32
12 13 8	+ 3 5	+ 4 22
12 14 37	+ 2 58	+ 4 12

The equation of time was $+3^m\ 15^s$, so that the apparent times of HEVELIUS seem about 20^s too small.

The sixth correction may be rejected on account of the discrepancy between the altitude and the time computed by HEVELIUS. The mean of all the other clock-corrections is $+4^m\ 1^s$, and there does not seem to be any sensible clock-rate.

Applying this correction, we have:—

Greenwich mean time of immersion of e^2 Aquarii . $8^h\ 1^m\ 1^s \pm 12^s$

Greenwich mean time of emersion of e^2 Aquarii . $8^h\ 50^m\ 55^s \pm 12^s$

Page 435.—*Occultatio Palilicii,* 1664, *die* ☽ *vesp.* 31 *Martii, quarta die post* ☌.

Temp. sec. hor. amb.

H. M. S.			
9. 14. 11.	Initium occult. Palilicii à ☽.		
9. 17. 30.	Altitudo Procyonis . . .	31.° 22.′ 0.″	Quad. p. Or.
9. 19. 35.	" " . . .	31. 10. 0.	
10. 4. 20.	Finis occult.		
10. 7. 50.	Altitudo Procyonis . . .	25. 2. 0.	
10. 9. 57.	" " . . .	24. 47. 0.	

The clock-corrections resulting from the four altitudes are:—

$$\begin{array}{ll}(1) & +10^{m}\ 20^{s}\\ (2) & +\ 9^{m}\ 58^{s}\\ (3) & +11^{m}\ 50^{s}\\ (4) & +11^{m}\ 43^{s}.\end{array}$$

I adopt the clock-corrections $+10^{m}\ 9^{s}$ for immersion, and $+11^{m}\ 46^{s}$ for emersion. The results are:—

Greenwich mean time of immersion . . . . . $8^{h}\ 9^{m}\ 44^{s} \pm 18^{s}$
Greenwich mean time of emersion . . . . . . $9^{h}\ 1^{m}\ 30^{s} \pm 18^{s}$.

Page 474.—*Eclipsis Solaris* 1666, 2 *Julii manè.*

Quantitas Phasium.	Temp. aestimatum secundum Horolog. Amb.	Tempus Correctum.				
	H. M. S.					
Initium.	6. 55. 30.	6. 57. 30.	$8\frac{3}{8}$.	7. 55. 45.	. . .	
$\frac{3}{8}$.dig.	6. 57. 30.	6. 59. 30.	$3\frac{3}{8}$.paulò minus	7. 59. 5.	. . .	
$\frac{3}{4}$.	7. 0. 23.	7. 2. 23.	$8\frac{1}{5}$.	8. 6. 30.	8. 8. 30.	
$1\frac{1}{8}$.	7. 2. 30.	7. 4. 30.	$7\frac{3}{4}$.	8. 11. 25.	8. 13. 25.	Hic, semid. ☽ ad 8″ vel 9″ major apparuit.
$1\frac{1}{2}$.	7. 4. 50.	7. 6. 50.	$7\frac{1}{4}$.ferè.	8. 17. 30.	8. 19. 30.	
$1\frac{3}{8}$.ferè.	7. 10. 57.	7. 12. 57.	7.ferè.	8. 19. 41.	8. 21. 41.	
$3\frac{3}{8}$.	7. 14. 59.	7. 16. 59.	$5\frac{7}{8}$.	8. 28. 8.	8. 30. 8.	
$3\frac{3}{4}$.	7. 17. 50.	7. 19. 50.	$5\frac{1}{2}$.ferè.	8. 30. 14.	8. 32. 14.	
$4\frac{3}{8}$.	7. 21. 35.	7. 23. 35.	$4\frac{3}{4}$.	8. 36. 25.	8. 38. 25.	
$4\frac{2}{3}$.	7. 23. 43.	7. 25. 43.	$3\frac{5}{8}$.	8. 43. 19.	8. 45. 19.	
$5\frac{1}{4}$.*	7. 27. 53.	7. 29. 53.	$3\frac{1}{4}$.	8. 46. 12.	8. 48. 12.	
6.	7. 31. 50.	7. 33. 50.	3.	8. 47. 32.	8. 49. 32.	
$6\frac{3}{4}$.	7. 36. 55.	7. 38. 55.	$2\frac{3}{4}$.	8. 50. 57.	8. 52. 57.	
$6\frac{7}{8}$.paulò plus.	7. 38. 5.	7. 40. 5.	$2\frac{1}{4}$.ferè.	8. 54. 15.	8. 56. 15.	
$7\frac{1}{8}$.	7. 39. 45.	7. 41. 45.	$1\frac{3}{8}$.	8. 58. 24.	9. 0. 24.	
$7\frac{1}{4}$.paulò plus.	7. 42. 30.	7. 44. 30.	$1\frac{1}{8}$.	8. 59. 35.	9. 1. 35.	
$7\frac{1}{2}$.	7. 44. 6.	7. 46. 6.	$0\frac{5}{6}$.	9. 1. 38.	9. 3. 38.	
$7\frac{2}{3}$.	7. 46. 0.	7. 48. 0.	$0\frac{1}{2}$.	9. 3. 20.	9. 5. 20.	
8.ferè.	7. 48. 25.	7. 50. 25.	Finis.	9. 6. 53.	9. 8. 53.	
$8\frac{1}{5}$.	7. 51. 15.	7. 53. 15.				
$8\frac{1}{4}$.paulò plus.	7. 53. 37.	7. 55. 37.	⊙ alt.			
⊙ alt.			47. 33. 0.	9. 23. 6.	9. 25. 28.	
17. 45. 0.	5. 51. 11.	5. 53. 12.	47. 42. 0.	9. 24. 16.	9. 26. 45.	
18. 37. 0.	5. 57. 5.	5. 59. 28.	48. 10. 0.	9. 28. 29.	9. 30. 40.	
18. 55. 0.	6. 0. 0.	6. 1. 28.	48. 28. 0.	9. 30. 36.	9. 33. 12.	

*Semid. ☽ aequalis extitit Solari.

The "notanda" which follow contain nothing worthy of remark.

The corrections to reduce the clock to mean time, as given by the individual altitudes, are as follows:—

Hor. amb.			Corr.	
h	m	s	m	s
17	51	11	+ 5	48
17	57	5	6	4
18	0	0	5	16
21	23	6	+ 5	53
21	24	16	5	58
21	28	29	5	36
21	30	36	5	56

The mean correction derived from the first group is $+5^m\ 43^s$, and from the last $+5^m\ 51^s$. The uncertainty of the corrections is as great as their difference; we therefore adopt the constant correction $+5^m\ 47^s$ to reduce the clock to mean time.

Page 550.—1671, *March* 14. *Occultation of two stars.*

				° ′ ″	
Hor. amb.	7. 16. 40.	Alt. Palilicii, ...	40. 36. 0.	Quad p. Or.
	7. 35. 30.	Alt. mer. Pollucis, ...	64. 23. 40.	Quad Az. M.
	8. 10. 20.	Alt. Palilicii, ...	33. 40. 0.	
	8. 12. 15.	" "	33. 29. 0.	
	8. 51. 0.	Stellula incognita supra medium caudam ♈ à ☽ corniculatâ tecta.		
	8. 54. 0.	Media caudâ ♈ à Luna têcta.		
		Alt. Palilicii, ...	27. 29. 0.	
	9. 42. 0.	Initium emersionis Mediae caudae ♈.		
	9. 57. 40.	Alt. Humeri dextri Orionis, .	22. 29. 0.	
	10. 0. 0.	" " " " .	22. 12. 0.	

The following are the results for clock-corrections:—

Clock Times.			Mean Times from Altitudes.			Clock-correction.		C′.	
h	m	s	h	m	s	m	s	m	s
7	16	40	7	27	47	+ 11	7	+ 11	0
8	10	20	8	21	58	+ 11	38	+ 11	53
8	12	15	8	23	18	+ 11	3	+ 11	55
8	54	0	9	6	9	+ 12	9	+ 12	37
9	57	40	10	12	14	+ 14	34	+ 13	41
10	0	0	10	14	17	+ 14	17	+ 13	43

The clock-corrections are quite uncertain, owing to uncertainty whether the difference of three minutes between the clock-correction given by Aldebaran and that given by α Orionis is the result of clock-rate, or of systematic error in the observations of one of the stars. If we suppose a rate of one minute per hour, the mean correction

will be as in the last column. I shall adopt this correction as on the whole the most probable. The results are:—

Greenwich mean time of immersion of star . . $7^h\ 48^m\ 58^s \pm 25^s$
Greenwich mean time of immersion of star . . $7^h\ 52^m\ 1^s \pm 25^s$
Greenwich mean time of emersion of star . . . $8^h\ 40^m\ 49^s \pm 40^s$.

I have not succeeded in identifying these stars. The descriptions would seem to refer to δ and ζ Arietis, but neither of them were near the computed position of the moon's limb at this time.

Occultatio Spica Virginis, 1671. 22 Aprilis.

	H. M. S.				H. M. S.
Horol. Amb.	9. 52. 45.	Altitudo Pollucis	35. 27. 0.	Temp. Corr.	9. 56. 21.
	9. 55. 20.	" "	35. 8. 0.		9. 58. 32.
	10. 45. 33.	Initium Occultationis. . . .			10. 47. 56.
	11. 15. 5.	Alt. ☽ limb. infer.	25. 50. 0.		11. 17. 25.
	11. 54. 0.	Spica necdum conspecta.			
	11. 55. 0.	Adhuc debitescebat.			
	11. 55. 30.	Spica emersit. Finis occult.			11. 57. 10.
	12. 0. 39.	Alt. Reg.	26. 18. 0.		12. 2. 14.
	12. 2. 9.	" "	26. 3. 0.		12. 4. 0.
	12. 36. 55.	Alt. Lyrae.	49. 39. 0.		12. 39. 45.
	12. 39. 23.	" "	49. 50. 0.		12. 41. 0.

Hevelius gives altitude of Regulus 36. 18. 0. at the moment of immersion; also, "Emersionsis Stellae accuratissime deprehensum est". The mean times computed from the altitudes compare with those of Hevelius as follows:—

Mean Times.			Diff. from Hevelius.		Clock-correction.	
h	*m*	*s*	*m*	*s*	*m*	*s*
9	54	52	— 1	29	+ 2	7
9	57	30	— 1	2	+ 2	10
10	46	42	— 1	14:	+ 1	9
12	1	9	— 1	5	+ 0	30
12	2	55	— 1	5	+ 0	46
12	38	21	— 1	24	+ 1	26
12	39	37	— 1	23	+ 0	14

The mean result is that at $11^h\ 26^m$ the clock-correction was $+ 1^m\ 12^s$. I shall admit a rate of — 24 seconds per hour. The results will then be:—

Greenwich mean time of immersion . . . . . $9^h\ 32^m\ 25^s \pm 15^s$
Greenwich mean time of emersion . . . . . $10^h\ 41^m\ 54^s \pm 15^s$.

Page 564.—Occultation of Saturn, 1671. June 1. manè. The times are so discordant that the observations seem worthless. Here, however, are the observations:—

Horolog. ambulat.				temp. corr.
2. 49. 50.	Altitudo Lyrae	71.° 8.′	. . . .	2. 50. 31.
2. 52. 0.	" "	70. 50.	. . . .	2. 53. 44.

2. 53. 32. Altitudo Lyrae . . . . dub. 70.° 32.′ . . . . 2. 56. 51.
3. 38. 15. ♄ Tegi incipiebat . . . . 3. 38. 15.
3. 38. 39. ♄ omnino tectus; alt. ☽ limb. inf. 16.° 57.′ . . . . 3. 38. 39.
3. 46. o. Alt. ☉ . . . . circa 1.° o.′ o.″ . . . . 3. 46. o.
5. 21. 21 " " . . . . 12. 40. . . . . 5. 22. 5.
5. 26. 58 " " . . . . 13. 17. . . . . 5. 26. 38.
5. 31. 29 " " . . . . 13. 42. . . . . 5. 29. 42.

Page 615.—*Occultatio Plejadum.* 1672. Novem. 6. manè.

H. M. S.
Horolog. amb. 12. 51. o. Plejadum praecedens omnium *a* Num. tecta à ☽.
1. 2. 45. In cuspide occid. *b* Num. 1 à ☽ tecta ad Stagnum Miris supra Paludem Maraeotidem.
1. 21. 31. Plejadum Lucidam proximè praecedens *d* tecta ad Montem.
h. m. s.
Acabe & Paludem Arabiae . . . . 1. 24. o.
2. 22. o. Altitudo Procyonis, 34.° 59.′ . . . . 2. 24. 15.
2. 24. 26. " " 35. 14. . . . . 2. 27. 3.

The altitudes of Procyon give:—

Mean Times.	Diff. from HEVELIUS.	Clock-correction.
h *m* *s*	*m* *s*	*m* *s*
14 7 27	− 16 48	− 14 33
14 10 5	− 16 58	− 14 21

The differences from HEVELIUS exceed the equation of time by 48^s and 58^s respectively. The clock-correction at $14^h\ 23^m$ is $-14^m\ 27^s \pm 17^s$. The interval of one hour and more between this time and that of the occultations considerably increases the uncertainty. The resulting Greenwich times are:—

Immersion of Coeleno . . . . $11^h\ 21^m\ 57^s \pm 30^s$
Immersion of Taygeta . . . . $11^h\ 33^m\ 42^s \pm 28^s$
Immersion of Maia . . . . $11^h\ 52^m\ 28^s \pm 25^s$.

Page 628.—*Occultatio Pleiadum.* 1673. Martii. 22. Die ☿, vesp.

Horolog. amb. 7. 21. 30. Altitudo Palilicii . . . 35.° 50.′ Temp. corr. 7. 24. 57.
7. 55. o. Praecedens Num. 1. *b*. In cuspide Occidentali Plejadum à Luna . . . tegebatur . . . . . . 7. 58. o.
7. 58. o. Plejadum una, sed Globo haud adscripta, tecta fuit . . . . 8. 1. o.
8. 7. o. Altitudo Palilicii . . 29. 39. . . . . . . 8. 10. 8.
8. 9. o. Alia Pl. N. 4. ex illis arctioribus duabus praecedens . . . rursus tecta . . . . 8. 12. o.
8. 14. o. Ex his posterior Num. 5. tecta fuit fere eo ipso ☽ loco . . . . 8. 17. o.
8. 57. 10. Altitudo Procyonis . . 36.° 55.′ . . . . . . 9. o. 52.

Comparison of HEVELIUS's times with the mean times computed from the altitudes:—

Mean Times.			Diff. from HEVELIUS.		Clock-correction.	
h	m	s	m	s	m	s
7	32	25	+ 7	28	+ 10	55
8	17	35	+ 7	27	+ 10	35
9	7	58	+ 7	6	+ 10	48

The mean clock-correction is $+ 10^m\ 46^s$, and there is no evidence of any sensible rate. Adopting this correction, the results are:—

Greenwich mean time of immersion of Taygeta . $6^h\ 51^m\ 10^s \pm 25^s$
Greenwich mean time of immersion of *m* Pl. . . . $6^h\ 54^m\ 10^s \pm 25^s$
Greenwich mean time of immersion of Asterope . . $7^h\ 5^m\ 10^s \pm 25^s$
Greenwich mean time of immersion of *l* Pl. . . . $7^h\ 10^m\ 10^s \pm 25^s$.

Page 658.—*Occultatio Pleiadum* 1674 Augusti 24. manè Die ♀.

Horolog. amb.	12. 57. 30.	Altitudo Aquilae 26. 51. dub. . temp. cor.	12. 59. 54.
	12. 59. 30.	" " 26. 31.	1. 2. 27.
	1. 37. 0.	St. inf. praecedens occultatu	1. 40. 0.
	2. 4. 30.	Praecedens omnium N. 1 Lunam subingressa.	2. 7. 30.
	2. 21. 30.	Inferiorum seq. N. 5. Lunam subiit . . .	2. 24. 30.
	2. 28. 0.	Praecedens omnium rursus in conspectum prodiit	2. 31. 0.
sic.	2. 39. 30.	Lucidam praecedens N. 4. circa limbum superiorem ☽ (ubi praeced. om.) tecta est	2. 39. 30.
	2. 47. 0.	Inferiorem praecedens sese rursus sistebat.	2. 50. 0.
	2. 57. 0.	Lucida Pl. sese subduxit	3. 0. 0.
	3. 0. 0.	Lucidam praecedens exiit	3. 3. 0.
	3. 6. 40.	Altitudo Markab. Pegasi. 39.° 23.′ . . .	3. 9. 38.
	3. 12. 20.	Inferiorem sequens emersit	3. 15. 20.
	3. 45. 15.	Altitudo Capitis Andromedae 54.° 12.′ .	3. 48. 16.
	4. 3. 55.	Lucida Plejadum N. 6. rursus illuxit . .	4. 6. 55.

The results of the altitudes are:—

Mean Times.			Diff. from HEVELIUS.		Clock-correction.	
h	m	s	m	s	m	s
13	1	38	+ 1	44	+ 4	8
13	4	10	+ 1	43	+ 4	40
15	11	10	+ 1	32	+ 4	30
15	49	52	+ 1	36	+ 4	37

The mean clock-correction is $+ 4^m\ 29^s$, which I shall consider constant. The mean times thus resulting are given in a subsequent section.

The equation of time is $+ 1^m\ 57^s$, so that the mean systematic difference from HEVELIUS is about 20^s.

Page 684.—*Occultation during lunar eclipse*, 1675, ♀, January 11, ev.

The clock-times are not given, but only those corrected.

H.	M.	S.	
8.	0.	50.	Stellula *b* tecta alt. M. Eoum; sed exire illam non deprehendi.
8.	35.	20.	Stellula suprema à Tergo Pollucis *c* omnino tecta.
8.	51.	25.	Stellula *d* ad ipsum Limbum inferiorem tecta.
9.	9.	10.	Haec eadem Stella *c* rursus emersit.

The altitudes from which the clock was corrected, taken before and after the eclipse, are given as follows:—

Tempus sec. horol. ex altit. corr. h	m	s		°	′	″
6	22	18	Altitudo Caudae Cygni .	39	3	0
6	25	4	Altitudo Caudae Cygni .	38	41	0
10	58	35	Altitudo Lucidae ♈ . .	28	52	0
11	11	33	Altitudo Capellae . . .	70	11	0
11	15	20	" " . . .	69	39	0
11	16	59	" " . . .	69	24	0
11	18	37	" " . . .	69	11	0

The mean times computed from certain of these altitudes compare as follows with the apparent times given by HEVELIUS:—

HEVELIUS'S App. Time.	Computed Mean Time.	Eq. Time.	App. Time.	App. Error of HEVELIUS.	Corr. to HEVELIUS on Mean Time.
h m s	*h m s*	*m s*	*h m s*	*m s*	*m s*
6 22 18	6 30 20	+ 8 55	6 21 25	+ 0 53	+ 8 2
6 25 4	6 33 5	+ 8 55	6 24 10	+ 0 54	+ 8 1
10 58 35	11 5 55	+ 8 59	10 56 56	+ 1 39	+ 7 20
11 11 33	11 18 57	+ 9 0	11 9 57	+ 1 36	+ 7 24
11 18 37	11 26 0	+ 9 0	11 17 0	+ 1 37	+ 7 23

The deviation of more than a minute from HEVELIUS is embarrassing; but I can get no other result from his altitudes than that given. I shall therefore take $+ 7^m\ 42^s$ as the corrections to reduce the times given by HEVELIUS to mean time, from which we shall have:—

	Local mean time.	Greenwich mean time.
Immersion of * *b*	$8^h\ 8^m\ 32^s$	$6^h\ 53^m\ 56^s$
Immersion of * *c* (85 Geminor.) . . .	$8^h\ 43^m\ 2^s$	$7^h\ 28^m\ 26^s$
Immersion of * *d*	$8^h\ 59^m\ 7^s$	$7^h\ 44^m\ 31^s$
Emersion of * *c* (85 Geminor.) . . .	$9^h\ 16^m\ 52^s$	$8^h\ 2^m\ 16^s$.

Page 714.—*Solar eclipse* of 1675, June 23, A. M.

He seems to have used no clock at all, but to have got all his times from a sundial, giving only the minutes.

Page 768.—*Eclipsis Solis.* 1676. Die Jovis 11 Junii *ante merid.*

Here it is a little doubtful how HEVELIUS got his times. His first column is on the first page headed "Juxta Sciater. & Horolog. Oscil.", and on the second page "Tempus juxta Sciatericum". But all the times are given accurately to seconds.

Juxta Sciater. & Horolog. Oscil.	Altitudo Solis.	Tempus ex alt. correctum	Magnit. Phasium Digit.				
7. 58. 10.	36. 17.′	7. 58. 18.	.	10. 22. 42.	. .	10. 22. 22.	$4\frac{1}{2}$. et paulò plus.
8. 1. 30.	36. 41.	8. 1. 6.	.	10. 26. 19.	. .	10. 26. 0.	$4\frac{1}{3}$. ferè.
8. 3. 30.	37. 3.	8. 3. 39.	.	10. 35. 24.	. .	10. 35. 6.	4. dig. 22′.
9. 22. 30.	. .	9. 22. 0.	Initium.	10. 38. 53.	. .	10. 38. 38.	$4\frac{1}{4}$. ferè.
9. 24. 10.	. .	9. 23. 40.	$\frac{1}{5}$. ferè.	10. 47. 34.	. .	10. 47. 20.	4. ferè.
9. 24. 55.	. .	9. 24. 25.	$\frac{1}{2}$.	10. 53. 49.	. .	10. 53. 30.	$3\frac{5}{8}$. ferè.
9. 27. 28.	. .	9. 27. 0.	$\frac{3}{4}$.	10. 58. 17.	. .	10. 58. 8.	$3\frac{3}{8}$.
9. 29. 40.	. .	9. 29. 10.	1.	11. 5. 27.	. .	11. 5. 20.	$2\frac{7}{8}$.
9. 33. 25.	. .	9. 33. 0.	$1\frac{1}{4}$.	11. 8. 50.	. .	11. 8. 44.	$2\frac{1}{4}$.
9. 36. 35.	. .	9. 36. 5.	$1\frac{5}{8}$. fer.	11. 22. 13.	. .	11. 22. 8.	$1\frac{3}{4}$. ferè.
9. 39. 35.	. .	9. 39. 10.	2.	11. 29. 14.	. .	11. 29. 10.	$1\frac{1}{10}$.
9. 45. 49.	. .	9. 45. 25.	$2\frac{1}{2}$.	11. 35. 25.	. .	11. 35. 20.	$\frac{1}{2}$.
9. 54. 22.	. .	9. 54. 0.	$3\frac{1}{8}$.	11. 36. 59.	. .	11. 36. 55.	$\frac{1}{4}$. paulò plus.
10. 3. 44.	. .	10. 3. 22.	$4\frac{1}{2}$.	11. 37. 55.	. .	11. 37. 53.	Nondum Sol om.
10. 8. 30.	. .	10. 8. 20.	$4\frac{3}{4}$.	11. 38. 35.	. .	11. 38. 35.	Nondum.
10. 18. 17.	. .	10. 18. 0.	$4\frac{1}{5}$. ferè.	11. 29. 15.	. .	11. 39. 15.	Nondum.
. . .	. .	. . .	.	11. 39. 40.	. .	11. 39. 40.	Finis Eclipseos.
. . .	. .	. . .	.	4. 18. 10.	33. 11.	4. 18. 19.	
. . .	. .	. . .	.	4. 20. 0.	32. 57.	4. 20. 36.	

Observed Semidiameters of the Moon.

H. M.	′ ″
10. 0.	13. 53.
10. 24.	14. 0.
11. 0.	14. 50.
Ultimò.	15. 0.

Page 774.—*Occultatio Martis et quarundam Fixarum* 1676 Sept. 1. *manè.*

	H. M. S.				
Hor. amb.	1. 1. 25.	Alt. Caudae Cygni	57.° 40.′	Temp. cor.	1. 0. 24.
	1. 36. 39.	Mars à Lunâ omninò tectus			1. 35. 42.
	1. 45. 25.	Alt. Caudae Cygni.	51. 17.	. . . .	1. 44. 7.
	2. 47. 54.	Mars emicuit; Finis nempè occultationis			2. 46. 29.
	2. 55. 0.	Alia Stellula Fixa *b* sub Marte egreditur			2. 53. 35.
	3. 19. 50.	Altitudo Scheat Pegasi. . . .	45. 3.	. . . .	3. 18. 19.
	3. 43. 45.	Fixa *c* ad Cuspidem Lunae inferiorem observata est.			3. 42. 20.

[Corresponds exactly with a MS. at the Paris Observatory.]

Animadvertenda.

De caetero notandum est, paullò post Martis egressum aliam insuper Stellulam Fixam *b*, Globo aliàs nondum adscriptam, vix ad 3 Min. prima infra Martem versùs Austrum, Horâ nimirùm

2 53′ 35″ exiliisse circa Paludes Amaras; quam quidem Lunam subire haud animadverti; cùm totus in eo fuerim, ut Martis momentum occultationis praecisè determinarem: * *

The results of the altitudes are:—

Mean Times.			Diff. from Hevelius.		Clock-correction.	
h	m	s	m	s	m	s
12	59	26	− 0	58	− 1	59
13	43	26	− 0	41	− 1	59
15	17	30	− 0	49	− 2	20

The mean correction is $-2^m\ 6^s$, which may be considered constant. The Greenwich mean times will then be:—

Immersion of Mars . . . . $12^h\ 19^m\ 57^s \pm 15^s$
Emersion of Mars . . . . $13^h\ 31^m\ 12^s \pm 15^s$
Immersion of b . . . . $13^h\ 38^m\ 18^s \pm 15^s$
Immersion (?) of c . . . . $14^h\ 27^m\ 3^s \pm 25^s$.

I have not succeeded in identifying the two stars. They are probably too small to be in the accurate catalogues.

Page 814.—*Occultatio duarum Stellularum in Clavâ Orionis* 1678. Mart. 28 ☽ vesp.

	H.	M.	S.	
Hor. amb.	7.	31.	0.	Luna tegit praecedentem in [illegible]va Orionis.
	9.	16.	0.	Luna tegit aliam Stellulam [illegible] ius incogn.*
	9.	17.	0.	Alt. Procyonis 33. 18. 0.
	9.	19.	0.	" " 33. 4. 0.

Nam illa praecedens in Clavâ Orionis hoc tempore anno sc. currente 1678 degit secundum nostrum Catalogum in 24° 21′ 10″ ♊ & Lat. 3° 11′ 24″ Aust; sic ut omninò illa ipsa fuerit, quae prius fuit obtecta. At de altera posteriori dubito, an ea ipsa fuerit, illa scilicet in clavâ Orionis sequens; Latitudo quidem ejus, quae est 3° 21′ 19″ Aust. occultationem non prohibet omninò, sed nihilominùs adeo arctam Synodum cum priori Stellulâ non concedit. * * * * 25° 17 ♊ & Lat. 3° 13′ A.

The clock-corrections resulting from the altitudes are, respectively, $+6^m\ 43^s$ and $+7^m\ 1^s$; mean, $+6^m\ 52^s$. The Greenwich mean times of the occultations will then be:—

First star, B. A. C. 1867 (?) . . . . $6^h\ 23^m\ 16^s \pm 45^s$
Second star, χ^2 Orionis (?) . . . . $8^h\ 8^m\ 16^s \pm 22^s$.

The two stars are those of the British Association Catalogue nearest the moon's limb; but it is doubtful whether they are really the occulted stars.

* In the original MS. at Paris the minutes were first 14, and were changed to 16.

From the Annus Climactericus of HEVELIUS, *Gedani, MDCLXXV.*

Page 7.—*Occultatio Lancis Austrinae* &c. 1679. Mart. 30. Manè.

Horol. amb.		Distantiae et Altitudines. gr. m. s.	Quo instrumento.	Temp. correc.
1. 48. 30.	Altitudo Reguli . . dub.	23. 27. 0.	Quadr. p. or.	. . .
2. 41. 0.	Minor Stella occultabatur .	. . .	.	2. 45. 0.
2. 48. 40.	Major Stella tegebatur . .	. . .	.	2. 52. 40.
2. 55. 0.	Alt. Arcturi	52.° 11.′	.	2. 59. 15.
2. 58. 0.	" "	51. 57.	.	3. 1. 0.
3. 16. 0.	" "	50. 3.	.	3. 21. 16.
3. 56. 40.	Emersio Minoris Stellulae .	. .	.	4. 0. 40.
4. 5. 15.	Emersio Majoris Stellulae .	. .	.	4. 9. 15.
4. 34. 0.	Alt. A[illegible]	40. 46.	.	4. 38. 29.
4. 36. 0.	"	40. 24.	.	4. 41. 14.

Stel. diff. in long. 4.′ 30.″ Lat. 3.′ ferè. Minor majorem sequatur in majori.
Lat. Bor. Long. ejus. 1660. 10.° 16.′ 0.″ ♏. et Lat. 0. 29. 30. B.

The results of the observed altitudes are :—

Mean Time.			Diff. from HEVELIUS.		Clock-correction.	
h	*m*	*s*	*m*	*s*	*m*	*s*
13	55	27 :	.	.	+ 6	57 :
15	4	0	+ 4	45	+ 9	0
15	6	40	+ 5	40	+ 8	40
15	26	22	+ 5	6	+ 10	22
16	43	21	+ 4	52	+ 9	21
16	46	5	+ 4	51	+ 10	5

Rejecting the doubtful altitude, the clock-correction at $15^h\ 49^m$ was $+ 9^m\ 30^s \pm 12^s$, which we shall suppose constant. There may be some suspicion of a gaining rate to the clock, but its effect on the mean of the observations would be small. The results will be :—

Greenwich mean time of immersion of α^1 Libræ . . $13^h\ 35^m\ 54^s \pm 22^s$
Greenwich mean time of immersion of α^2 Libræ . . $13^h\ 43^m\ 34^s \pm 20^s$
Greenwich mean time of emersion of α^1 Libræ . . $14^h\ 51^m\ 34^s \pm 15^s$
Greenwich mean time of emersion of α^2 Libræ . . $15^h\ 0^m\ 9^s \pm 16^s$.

Page 18.—*Occultatio* ♃, 1679. Junii 5. *manè*. (rose at 15^h 35^m.)

Hor. Amb.		Distantiae & altitudines.		Tempus correct.
		° ′		H. M. S.
1. 18. 55.	Alt. Capitis Andromedae	24. 52. .	. . . .	1. 20. 54.
1. 29. 0.	Alt. Arcturi	31. 3. .	. . . .	1. 31. 24.
4. 15. 40.	Jupiter stringebat ☾ limbum	. . .	. . . .	4. 18. 5.
4. 16. 9.	" ad centrum usque occultabatur . .	. . .	. . . .	4. 18. 34.
4. 16. 35.	Jupiter totus omnino tectus	. . .	. . . .	4. 19. 0.
5. 14. 0.	Jupiter denus exire votabili particulâ videbatur	. . .	. . . .	5. 16. 25.
5. 14. 20.	Dimidius Jupiter exiverat	. . .	. . . .	5. 16. 45.
5. 14. 45.	Totus Jupiter omnino prodiit	. . .	. . . .	5. 17. 10.
		° ′ ″		
10. 22. 30.	Altitudino Solis	53. 34. 40.	. . . .	10. 25. 2.
10. 27. 16.	" "	53. 59. 45.	. . . .	29. 42.
10. 30. 8.	" "	54. 14. 0.	. . . .	32. 26.
10. 38. 0.	" "	54. 53. 40.	. . . .	40. 26.
10. 45. 28.	" "	55. 27. 20.	. . . .	47. 46.

Results of the observed altitudes:—

Object.	Mean Time.	Diff. from HEVELIUS.	Clock-correction.
	h m s	*m s*	*m s*
a Andromedæ	13 18 50	− 2 4	− 0 5
Arcturus .	13 29 4	− 2 20	+ 0 4
Sun . . .	10 22 44	− 2 18	+ 0 14
" . . .	10 27 9	− 2 33	− 0 7
" . . .	10 30 12	− 2 14	+ 0 4
" . . .	10 37 54	− 2 32	− 0 6
" . . .	10 45 13	− 2 33	− 0 15

The mean clock-correction is -2^s, without any sensible rate. The Greenwich mean times of the observed phases are:—

Immersion.		Emersion.	
Contact of limbs . .	$15^h\ 1^m\ 2^s \pm 7^s$.	Partly emerged . .	$15^h\ 59^m\ 22^s \pm 7^s$.
Jupiter half covered .	$15^h\ 1\ 31^s \pm 7^s$.	Half emerged . .	$15^h\ 59\ 42^s \pm 7^s$.
Jupiter entirely hidden	$15^h\ 1^m\ 57^s \pm 7^s$.	Entirely emerged .	$16^h\ 0^m\ 7^s \pm 7^s$.

Page 27.—1679. Junii 24. *vesp. Occultatio duarum stellularum in ♐.*

Hor. amb.		Distantiae & altitudines.	Quo instrumento.	Tempus correct.
h. m. s.		° ′		
10. 39. 55.	Altitudo Arcturi	42. 48.	Quad. p. or.	10. 44. 22.
10. 41. 51.	" "	42. 31.	. . . .	10. 46. 32.
11. 0. 8.	Initium occultationis ✱ majoris	. .	. . . .	11. 4. 28.
11. 40. 55.	Exitus ejus Stellae in ♐	. .	. . . .	11. 45. 15.
12. 11. 48.	Alt. Arcturi	39. 58.	. . . .	12. 16. 20.
12. 13. 8.	" "	29. 45.	. . . .	12. 17. 49.
12. 17. 25.	Alt. Lucidae Coronae	46. 9.	. . . .	12. 21. 42.
12. 19. 19.	" " "	45. 53.	. . . .	23. 36.
12. 22. 52.	" " "	45. 23.	. . . .	27. 10.
Major illla stella est media illa in praecedente fascia, ♐.				

Results of the observed altitudes :—

Star.	Mean Times.	Diff. from HEVELIUS.	Clock-correction.
	h m s	*m s*	*m s*
Arcturus	10 45 57	+ 1 35	+ 6 2
"	10 48 5	+ 1 33	+ 6 14
"	12 17 55	+ 1 35	+ 6 7
"	12 19 26	+ 1 37	+ 6 18
α Coronæ	12 22 25	+ 0 43	+ 5 0
"	12 24 19	+ 0 43	+ 5 0
"	12 27 54	+ 0 44	+ 5 2

The difference of more than a minute between the clock-corrections given by the two stars is quite embarrassing, and the more so that HEVELIUS's calculation makes them nearly agree. The equation of time was 1 45^s, so that the error, whatever it is, seems to be in the computations relating to *α* Coronæ. The positions which I have adopted for the stars are :—

$$\text{Arcturus, R. A.} = 14^h\ 1^m\ 4^s;\ \text{Decl.} = +20^\circ\ 52'.5\,;$$
$$\alpha\ \text{Coronæ, R. A.} = 15^h\ 21^m\ 7^s;\ \text{Decl.} = +27^\circ\ 49'.5.$$

In the observations of 1663, August 18, the same two stars were observed, and there HEVELIUS's computations agree with mine. At present, the only course seems to be to reject the altitudes of *α* Coronæ entirely, and adopt the clock-correction $+6^m\ 10^s$ resulting from the altitudes of Arcturus, which, it will be seen, is only about 10^s greater than that resulting from HEVELIUS's computations of *α* Coronæ, when corrected for the equation of time. The results are then :—

Greenwich mean time of immersion of *ρ* Sagittarii . $9^h\ 51\ 42^s \pm 6^s$
Greenwich mean time of emersion . . . . $10^h\ 32^m\ 29^s \pm 6^s$.

Page 110.—*Occultatio Palilicii.* 1681. Jan. 1.

Hor. amb.			
7. 37. 0.	Stella occultata est. alt. capite Androm.	50. 32.	7. 37. 33.
7. 46. 0.	Altitudo Capitis Andromedae . . .	49. 24.	7. 46. 11.
7. 49. 30.	" " "	48. 55.	7. 49. ·8.
8. 46. 0.	Palilicium rursus affulsit	. .	8. 44. 0.
8. 51. 0.	Alt. Cap. Androm. extitit	40. 22.	8. 49. 8.

Results of the altitudes:—

Mean Times.	Diff. from Hevelius.	Clock-correction.
h m s	m s	m s
7 42 37	+ 5 4	+ 5 37
7 51 14	+ 5 3	+ 5 14
7 54 53	+ 5 45	+ 5 23
8 55 55	+ 6 47	+ 4 55

Here again there seems to have been an error in Hevelius's computations of apparent time. But there is little doubt of the mean clock-correction $+5^m\ 17^s \pm 8^s$; applying which, we have:—

Greenwich mean time of immersion . . . . $6^h\ 27^m\ 41^s \pm 20^s$

Greenwich mean time of emersion . . . . $7^h\ 36^m\ 41^s \pm 17^s$.

Page 139.—*Occultatio Palilicii.* 1683. Jan. 9. *vesp.*

Hor. amb.				
8. 54. 30.	Alt. Pollucis	48. 48.	Quad. p. or.	9. 0. 5.
8. 55. 15.	" "	48. 53.	. .	9. 1. 22.
9. 42. 15.	Initium occultationis	. .	. .	9. 48. 15.
9. 50. 40.	Alt. Reguli	24. 12.	. .	9. 56. 35.
9. 54. 15.	" "	24. 40.	. .	9. 59. 51.
10. 55. 30.	Finis occultationis Pal.	. .	. .	11. 1. 30.
11. 3. 58.	Dist. Pal. ab occ. ☾ limb. 7. rev. .	. .	′ ″ 5. 19.	9. 58.
11. 9. 10.	" " " 10.	. .	7. 36.	15. 10.
11. 13. 20.	" " " 12.	. .	9. 7.	19. 20.
11. 19. 12.	Alt. Reguli	36. 16.	. .	11. 25. 32.
11. 21. 2.	" "	36. 22.	. .	11. 26. 20.
11. 23. 20.	" "	36. 40.	. .	11. 28. 46.

From the altitudes we have :—

Star.	Mean Times.	Diff. from HEVELIUS.	Clock-correction.
	h m s	m s	m s
Pollux	9 8 14	+ 8 9	+ 13 44
"	9 8 49	+ 7 27	+ 13 34
Regulus	10 4 49	+ 8 14	+ 14 9
"	10 8 4	+ 8 13	+ 13 49
'	11 33 47	+ 8 15	+ 14 35
"	11 34 36	+ 8 16	+ 13 34
"	11 37 3	+ 8 47	+ 13 43

The mean clock-correction is $+13^m\ 53^s \pm 6^s$, which seems to have been constant. We then have :—

Greenwich mean time of immersion . . . . $8^h\ 41^m\ 32^s \pm 8^s$
Greenwich mean time of emersion . . . . $9^h\ 54^m\ 47^s \pm 8^s$.

Page 145.—*Occult. duarum* ∗ *sub cornu aust.* ♉. 1683. apr. 2. *vesp.*

Hor. amb.				Tempus correct.
9. 53. 0.	Initium occul. Stellae Maj. A. 5. mag. .			9. 54. 30.
10. 29. 36.	" " Stellae B. 6. mag. . .			10. 30. 36.
10. 52. 50.	Finis occult. St. A.			10. 53. 50.
11. 43. 30.	Alt. Lyrae .	31.° 25.′	. . . .	11. 44. 16.
11. 45. 30.	" " .	31. 44.	. . . .	. 46. 47.
11. 46. 30.	" " .	31. 55.	. . . .	. 47. 42.
11. 47. 30.	" " .	32. 6.	. . . .	. 49. 27.

The altitudes of α Lyræ give :—

Mean Times.	Diff. from HEVELIUS.	Clock-correction.
h m s	m s	m s
11 48 17	+ 4 1	+ 4 47
11 50 40	+ 3 53	+ 5 10
11 52 1	+ 4 19	+ 5 31
11 53 22	+ 3 55	+ 5 52

The mean correction is $+5^m\ 20^s \pm 14^s$, which corresponds to the clock-time $11^h\ 46^m$. We have no data for clock-rate; but for several years it has appeared too small to be indicated by such observations as HEVELIUS could make. Applying this correction to the occultations, the Greenwich mean times are :—

Immersion of 119 Tauri . . . . $8^h\ 43^m\ 44^s \pm 24^s$
Immersion of 120 Tauri . . . . $9^h\ 20^m\ 20^s \pm 20^s$
Emersion of 119 Tauri . . . . $9^h\ 43^m\ 34^s \pm 18^s$.

§ 10.

OBSERVATIONS OF ECLIPSES AND OCCULTATIONS MADE BY ASTRONOMERS OF THE FRENCH SCHOOL BETWEEN 1670 AND 1750, AS FOUND IN THE MANUSCRIPT RECORDS OF THE PARIS AND THE PULKOWA OBSERVATORIES.

We now pass to a class of observations much more satisfactory than those with which we have been dealing. In the latter part of the seventeenth century, PICARD and other French astronomers introduced the improved method of determining the time by equal altitudes of the sun, of which I have already spoken.* Their clocks were so far improved that their principal changes of rate were those due to changes of temperature. I include in the present section all the observations for which the time was determined on this plan, including those of DELISLE in St. Petersburg. They are for the most part unpublished. The results of a few have indeed appeared in the old Memoirs of the French Academy, and in the *Philosophical Transactions*, but these are not by any means the most valuable ones for our present purpose. Besides, they were reduced with the imperfect data of the time, and need a more careful reduction before the best results can be obtained from them. As an example of the danger of trusting to the old reductions, it may be remarked that occultations were often observed by CASSINI with a different clock from that used for observing the meridian observations of the sun. But in communicating the result of one of these observations to the Academy, he failed to correct it for the difference of clocks, so that it appears printed in the Memoirs more than a minute in error.

Four occultations of the Pleiades, observed by DELISLE at St. Petersburg, were reduced by LINSSER, of the Pulkowa Observatory, and published in the Memoirs of the St. Petersburg Academy.† But observations of occultations were made by DELISLE during a large part of his stay at St. Petersburg, which are to be included in any complete discussion of the subject

In March, 1871, the late M. DELAUNAY, then director of the Paris Observatory, very kindly placed the whole of its older archives at my disposal, with unrestricted permission to extract from them, and use in my investigations, whatever I might find of value for the work in hand. Two years later a similar permission to complete my copies in certain points was granted by M. LE VERRIER. As a result of this permission, I am enabled to present the observations discussed in the present section.

Of the records to be used, a large portion were evidently never intended to be understood or used by any one but the observers. For the most part, the note-books contained no titles, no indications of the observer, no verbal statement of the observation, and no name or indication of instruments, except in the case of clocks. All information on these points had to be gained by comparison and induction. It was found that a certain arrangement of figures, which the reader soon learned to recog-

* See *ante*, pp. 23–24.

† *Vier von De l'Isle beobachtete Plejaden-Bedeckungen, bearbeitet und mit* HANSEN'S *Mondtafeln verglichen, von* CARL LINSSER. St. Petersburg, 1864.

nize, showed observations of equal altitudes of the sun before and after noon, and that the signs |(and)| indicated the transits of the two limbs of the sun over the meridian of some instrument. Each observer seems to have had his own instruments, which he used without any reference to or comparison with the instruments of others.* In many cases, especially among the earlier observations, no designation of the occulted star by which it might be identified was given. In these cases, it was necessary to compute the tabular place of the moon, as affected by parallax, for the time and place of the occultation, and then to ascertain from the modern catalogues or star-maps what stars were then near contact with the limb of the moon. I believe this operation, though laborious, was always successful, except in a few cases of stars too faint to be found in catalogues.

In the following pages, the intention is to present literal copies of extracts from the original records It is not, however, always practicable to do this with entire rigor. In the case of some observers, especially of DELISLE, the observations were given at such length, and mixed with so many extended remarks, that a condensed summary was absolutely necessary. These summaries can always be distinguished from verbatim copies by being written in English. In printing the following discussion of the observations, a sharp distinction is made between two classes of matter, namely, (1) remarks made at the time of examining the original observations, while the writer was in entire ignorance of the nature of the results; and (2) the ulterior reductions, made when the original records were no longer accessible. The former, as well as the literal copies from the records, are distinguished by being printed in smaller type, so that the reader can readily distinguish them from the latter. The arrangement is made on the following plan:—The observations are divided into four series, each of which are made by one set of observers, or on a common plan, or with the same instruments. Perhaps it would be more accurate to say that the different series correspond to different sets of volumes found among the archives of the Paris Observatory; certainly, this is the only real distinction I can now make between series I and series IV. Preceding each series is given such general discussion of the observations as applies to the whole of it. Each series is divided into groups, each group comprehending such observations as could be conveniently discussed together, and the reduction and discussion of the observations of each group are given immediately after the observations which belong to it. In the case of series IV, however, all the earlier observations are made and reduced on a plan so nearly uniform that it has not been deemed necessary to go into the separate details of reduction of each observation.

It may happen that in some cases the relation of the observations to each other, and the bearing of the remarks on them, will not be clear. This is owing to several disadvantageous circumstances. Some of the archives examined were misarranged through mistakes of the cataloguer; the copies were made during the reign of the Commune and the siege of Paris by the national forces, and were therefore somewhat

* In this connection, it may not be amiss to call attention to the wide-spread error, found even in French histories of astronomy, that CASSINI I. was director of the Paris Observatory. In fact, this establishment was assigned to the common use of the astronomers of the Academy of Sciences, and no such office as that of director was known or recognized. The celebrity of CASSINI seems to have given rise to the unfounded impression that he exercised a supervision over the work of the other astronomers.

hurried; in reading proof, no access to the originals could be had. These circum stances are the only apology I can present for any crudity of arrangement which may be noticed.

Examination of Manuscripts at the Paris Observatory.

SERIES I.

There are curious duplicate copies of the earlier observations at Paris. (1) We have a volume entitled *Histoire Céleste de l'Observatoire Royal de Paris*, vol. 1, 1671–1675. But vol. 2, with the same title, does not begin until 1783, and the similarity of the volumes following 2 to volume 1 seems to show that they were not prepared until a comparatively late date.

(2) There is another volume, entitled *Fragmens des Relevés des Registres de l'Observatoire Royal de Paris*, in which the observations of 1672, 1673, 1680–1684, 1700–1703, 1760–1767, are copied on printed forms, with the heading *Histoire Céleste de l'Observatoire Royal de Paris*, which was prepared by CASSINI IV. for publication, but never published.

These two volumes seem to be in the same handwriting, namely that of CASSINI IV. Yet, while much of the matter in the two is common, each contains observations and remarks not given in the other. For instance, in the case of the occultations of February 3, 1672, (2) says that the clock stopped about 5¼ hours p. m., and that it stopped very frequently about this period. There is no complaint of the clock at all in (1). Yet the observations agree perfectly. But of the altitudes for time copied from (1) only a very few are found in (2). More curious yet is the comparison of the accounts of an occultation in 1672 given in the two registers, which I copy verbatim.

From (1), page 32.—" Le 2 Aoust. Vers les 9^h. du soir la lune etoit proche d'une etoile fixe voisine d'Antarés qu'elle a eclypsée au moment de l'immersion (qu'on a oublié de marquer sur le registre) la distance ou la differ. de declin. du bord austral de la lune et de l'etoile etoit de $1' \, 3''$."

From (2), p. 42.—"Aoust le 2. Vers les 9^h. du soir, la lune s'approchoit d'une etoile voisine du coeur du Scorpion que l'on a jugé devoit être eclypsée. Le parallelle de l'etoile parait quelques minutes au midi de la tache de Copernic.

" $10^h. \, 21'. \, 34''$. Occultation de l'etoile par la lune ($10^h. \, 22'. \, 11''$. T. vr.)"

We find also that in (2) the use of the astronomical day is introduced, instead of the old divisions "matin", "soir", and we have the following clock-errors and transits:—

Aug. 2.	8^h	$22'$	$0''$	Pend. retard		$0'$	$35''$
	12	17	5	β versau au merid.	34°	$12'$	$55''$
	14	44	0	Mars " "	32	57	30
	15	13	0	Saturn " "	39	37	40
3.	9	56	0	Pend. retard		$0'$	$42''$
	10	35	0	α Aquilae.			

[In (1), $10^h \, 34' \, 40''$ is given for the time of transit of α Aquilae.]

But there is no indication how these clock-errors were obtained, and no observations in either book to fix clock-errors at these times.

I infer from this, and also from remarks of CASSINI, that both volumes are simply excerpts from registers which cannot now be found, and that the observations of different persons are mixed together.

The clock-error would seem from what follows to be well determined, unless the instruments for determining it were erroneous. But the times of transits which follow

do not agree with this error at all. In fact, we have from the transits of β Aquarii and α Aquilæ:—

	1672, Aug. 2.	Aug. 3.
	h m s	h m s
Right ascension of star . . .	21 14 17	19 34 48
Mean time of transit	12 24 58	10 41 50
Apparent times	12 19 27	10 36 24
Clock-times	12 17 5	10 35 0
Clock apparently slow	2 22	1 24.

Either the meridian instrument was defective, and not used for clock-error, or observations with two clocks are mixed together. As the method of equal altitudes was known and practised at this time, I think we may take the clock-correction given as probably near the truth, so that we shall have:—

	h m s
Apparent time of an occultation of τ Scorpii, 1672, Aug. 2	10 22 11.
Equation of time	5 31.6
Paris mean time	10 27 42.6
Greenwich mean time	10 18 21.6.

In view of a certain probability that the clock-error was well determined, the probable error of this time may be estimated at $\pm$ 6^s; but the probability of the error being four times as large as this is much greater than would result from the application of the usual theory of errors to the supposed probable error.

From (2).—1680, April 4. 10^h 25′ 7″. Occultation d'une etoile par la lune.

Midy le 2.	11^h	59′	36″	à la ligne.
3.	0	0	15	
4.	11	59	55	
6.	0	0	16.	

We can only use this as apparent time. The discordant meridian transits of the sun which follow do not indicate any readily determined correction of the clock on apparent time. The equation of time being + 2^m 36^s, we have:—

Paris mean time of occultation of Lalande 12148 . .	10^h 27^m 43^s
Greenwich	10^h 18^m 22^s.

The probable error may be $\pm$ 12^s. The extraordinary coincidence between the mean times of this and the last occultation seems to be accidental.

On 1682, Feb. 15, we find the occultations of the Hyades recorded as follows:—

$\left.\begin{array}{l} 6\ 59\ \ 2 \\ 7\ \ 1\ 27 \end{array}\right\}$ Occultation des deux etoiles qu'on a observées après la lune.

The times are marked in the column "Temps vray", which, however, contains elsewhere only clock-corrections. Preceding it we have a set of corresponding altitudes of ☉ for clock, evidently independent of those of La Hire, hereafter quoted, and giving a clock-correction of $-24^s.3$, nearly half a minute different from the correction of La Hire's clock. Yet the occultation must be that observed by La Hire [given hereafter].

For this date we have $+ 14^m 41^s$ for the equation of time. This would make the mean times of the occultations, as reduced by the unknown computer:—

	h	m	s
θ_1 Tauri	7	13	43
θ_2 Tauri	7	16	8

which are 9^s less than those which we shall find to be given by LA HIRE's observations. This, then, may be regarded as the error of reduction in the present case.

Observations by CASSINI *and* MARALDI.

There is a series of registers, in small quarto, for the years 1683 onward, without original title or paging, containing rough notes of observations.* The only title is *Observations du Soleil et des Etoiles faites en Boulogne et en Paris l'an* 1683, *et continuées à Paris la même année et la suivante.* No mention of the observer, but there is little doubt that it was J. D. CASSINI.

EXTRACTS.

1683. *Occultation of γ Tauri, Feb.* 5.

Feb. 4. Hauteurs Rigel.	5 8 13	23 0 0
	12 47	23 30 0
	17 26	24 0 0.

Feb. 5 (probably a. m.).

9 16 53 h. inf. bord ♀	24 2 0	0 0 57	midy a la m. A.
22 9	24 30 10	0 0 58	" a la m. B.
26 35	25 0 0		

2 9 $37\frac{1}{2}$ / 9 46	1 b ♀ / 2 b	24° 30′ 0″
14 17 / 14 26		24 0 0
18 $51\frac{1}{2}$ / 19 1		23 30 0
23 $19\frac{1}{2}$ / 23 $28\frac{1}{2}$		23 0 0
27 44 / 27 $52\frac{1}{2}$		22 30 0
32 3 / 32 $12\frac{1}{2}$		22 0 0
36 17 / 36 $26\frac{1}{2}$		21 30 0

Feb. 5 (probably a. m.). Hauteurs lepy delav.

6 18 29	23 30 0
23 $6\frac{1}{2}$	23 0 0
27 53	22 30 0
32 $12\frac{1}{2}$	32 0 0
7 5 $33\frac{1}{2}$	18 0 0
9 $35\frac{1}{2}$	17 30 0
17 20	16 29 15

P. M. Hauteurs Rigel.

5 13 19	23 59 0
5 18 16	24 31 0
10 4 $32\frac{1}{2}$	24 31 5
9 37	23 59 0

7 41 26 Rigel au merid. par les h. corres.

$12^h\ 0'\ 8''$, occultation de l'etoile qui est a la point de l'angle du Hyades par la lune.

1683. Feb. 6.

0 1 9 midy a la m. *a*.

0 1 10 " " " *b*.

We shall derive the clock-correction from the meridian transit of Rigel, as

* This is really the regular series of the records of the Observatory, and is continued until 1795; but a part of it has been copied into another series, which I have sometimes used to copy from, and the cataloguer has confused the original with the copy

deduced from the equal altitudes, and the rate from transits of the sun over the two meridian-marks on February 5 and 6. We have:—

	h	m	s
Mean R. A. of Rigel, 1683.1	4	59	20.1
Sid. time of mean noon, 1683, Feb. 5, Paris	21	2	52.2
Mean time of transit of Rigel thence computed	7	55	9.9
Correction of clock on mean time, ...	+	13	44.1
Mean time of transit of sun, Feb. 5, 0^h 14^m $42^s.3$; Feb. 6,	0	14	45.8
Correction of clock (mean of marks) + 13 44.8	0	13	36.3
Correction of clock for occultation of γ Tauri	+	13	42.6
Paris mean time	12	13	50.6
Greenwich mean time	12	4	29.6.

Eclipse of July 12, 1684.

Le 12 Julliet, a 6^h. Therm. 79½. Bar. 28.0.

Haut. du bord sup. du ☉

6 24 50	20 40
27 57	21 10
31 2	21 40
9 2 26	46 10 (?)
5 51	46 30
9 23 39	49 20

Aprè: midy on a avancé l'horloge de 16″. L'Eclipse. À 2 28 30 Elle etoit commencée, fin 4 43 12. L'horloge de M. de la Hire avancoit sur le notre 5′ 57″. Il a observé la fin a son horloge a 4^h 49′ 9″.

But there is some doubt as to which clock the writer used.

4^h 42′ 56″ horloge de la tour occidentale = 4 45 0 horl. de la tour orientale. D = 2′ 4″.

1684. Le 13 Juillet. Hauteurs du bord sup. du ☉

10 9 55	55° 30′ 8″	1 49 13½
12 33	55 50 8	1 46 32
18 10½	56 30 0	1 40 59
21 2	56 50 0	1 38 7
23 57	57 10 12	1 35 12
26 54½	57 30 12	1 32 13
33 2	58 10 0	1 26 5

I make no use of these observations of the eclipse. The beginning appears not to have been seen. The coincidence of the time of ending with that derived from the observation of La Hire renders it doubtful whether the end was actually observed either. The results of these and other observations are given in the *Mémoires*, tome x, p. 667, where Cassini's time of beginning is said to be 2^h 25^m 55^s, and of end 4^h 43^m 23^s. Either the same clock-error has not been used at beginning and end, or the time of beginning is in some way altered.

1684 le 19 Decembre. Hauteurs du bord sup. du Soleil.

9 28 10	2 35 32	10 20 0
9 35 23	2 28 22	11 0 0
12 0 31	1 Bord ☉	
12 2 54	2 " "	
2 23		
12 1 34	Midy a la Marque Q	
12 2 3	Midy a la Marque D contre la Muraille.	
12 1 51½	Midy par les corresp.	

À 2^h 40 l'horloge orientale avance 47″ sur l'occ. J'ay osté deux minutes a l'horloge occidentale et j'ay mis avec elle l'orientale.

Le 20 Decembre.

11 58 50	1 Bord ⊙	9 59 18	2 0 42 *a*	13 10 0
12 1 12½	2 "	10 1 28	1 58 35 *b*	13 20 0
		10 3 38	1 56 28	13 30 0
2 22½				
11 59 50	Midy par l'omb.			
12 0 22	a la Marque D.			

I judge that the following are altitudes of the sun observed on the morning of the 21st, with a mistake in the hour, 2 being written for 9. There is a blank space left for the corresponding afternoon altitudes.

	2 32 4	10 50 0
	33 55	11 0 10
	35 52	11 10 30
	29 26	11 30
A midy nebuleux	43 20	11 50 10
	47 13	12 10 0
	51 15	12 30 10

Le 21 Decembre.

Commencement de l'eclipse 9^h 29′ 8″.
18

35′ 6″ L'Etoile se cache derriere la lune.
— 18 [Evidently a subsequent insertion.]
10^h 8′ 58″ L'Etoile paroist. [Under this another time is given for the same phenomenon, apparently 9′ 10″, but it is erased with the pen, and 8′ 58″ is substituted.]

Le 22 Decembre.

12 0 11	I Bord ⊙	9 14 46	9 10 0
12 2 34	II "	18 5 douteuse.	9 30 0 douteuse.
12 0 42	Midy a la Marque D.	9 21 31	9 50 0
		24 57½	10 10 0
		28 30	10 30 0
		32 6	10 50 0

à 10^h l'hor. oriental avance sur l'occ. 5″.

Le 23 Decembre.

Noon per single pair of altitudes, 12^h 0^m 30^s.

Le 24 Decembre.

12 0 55	1 Bord du ⊙	9 14 52	2 46 54	9 10 0
12 3 15½	2 " " "	18 11	2 43 34	9 30 0
12 0 34	Midy a la Marque Q	21 37	2 40 8	9 50 0
12 1 16	Midy non pass. a la Marque D	25 13	2 36 32	10 10 0
		28 36	2 33 11	10 30 0
		32 12	2 29 36	10 50

These observations from 1684, December 19 to December 24, are given here for the purpose of reducing the occultation of μ Geminorum, observed during an eclipse of the moon, on the evening of December 21. The same occultation was observed by La Hire, with a much more certain determination of clock-error; but I have

thought it worth while to reduce these observations also, although there has been some difficulty in unravelling them, owing to the three meridian-marks or instruments on which the sun-transit was observed, and the general confusion of the records. The mode of proceeding has been as follows:—From the equal altitudes of the sun on December 20 and December 24 the index-error of the quadrant was derived. Taking this index-error for the altitudes observed on December 21 and December 22 (a. m. civil time), the sun's hour-angle was computed for each of these observations. The clock-corrections thus deduced from the altitudes alone, reduced to noon, were:—

Date.	Corr. on Apparent Time.	Equation T.	Corr. on Mean Time.
1684.	s	m s	s
Dec. 19	+ 8.0	− 1 40.7	− 92.7
20	− 1.5	− 1 10.5	− 72.0
21	− 17.0	− 0 40.4	− 57.4
22	− 24.0	− 0 10.2	− 34.2
23	− 30.0	+ 0 20.0	− 10.0
24	− 50.8	+ 0 50.1	− 0.7

The correction of the clock for the phases of the occultation appears to be $-48^s.2$ and $-47^s.3$, with a probable error of perhaps 3^s. There is no certain evidence that the clock used was the same with that with which the altitudes were noted, but the close coincidence between the figures, − 18, written under the observed seconds of immersion, and the correction of the clock on apparent time, make it probable that the clocks were the same. The correction -18^s is that actually applied by CASSINI, as appears from the publication of his result in the Memoirs of the Academy, vol. x, p. 674. The time there given is $9^h\ 34^m\ 48^s$.

The emersion is to be received with suspicion owing to the double record, and the possibility that the observer did not catch the star when it first emerged.

1686, Apr. 10. Occultation of Jupiter observed, but no sufficient data for clock-correction.

Occultation of unknown star, 1686, June 25, $9^h\ 53'\ 51''$ p. m. clock.

June 24, ⊙ altitudes.

	10 31 0	59 20 0	59 33	0 50 midy.
	33 54	59 40 0	1 54	
	37 0	60 0 0		
June 25.	0 53 midy.	9 53 51 une fixe dans la parte obscure ☽.		
June 26.	haut. du bord du soleil.			
	9 34 11	52 0	11 58 48	2 18
	9 37 48	52 30	1 6	
	9 41 7	52 59		
	44 49	53 30		
	48 23	54 0 5	cette derniere seule est bonne.	
June 27.	11 58 54 |(			
	0 0 3 | centre (?).			
June 28.	$9^h\ 33'\ 43''$	$51^\circ\ 50'\ 10''$	$2^h\ 26'\ 26''$	
	37 10	52 20 10	2 22 49	
June 29.	11 59 3 |(			
	0 1 21)|			

The clock-times of apparent noon, as they follow from the meridian-mark and from the altitudes, are as follows:—

	Mark.	Altitudes (corrected for rate).
June 24	$0^h\ 0^m\ 43^s.5$	$0^h\ 0^m\ 38^s.5$
25	$0^h\ 0^m\ 53^s$:	
26	$11^h\ 59^m\ 57^s$.	$11^h\ 59^m\ 53^s$
27	$0^h\ 0^m\ 3^s$:	
28		$0^h\ 0^m\ 3^s.5$.
29	$0^h\ 0^m\ 12^s$.	

The clock appears to have been put back a minute on June 25, and there is no way of determining whether it was done before or after the occultation. The correction on apparent time at $9^h.9$ was either -51^s or $+9^s$. The equation of time is $+2^m\ 2^s$. We have therefore:—

Correction of clock on mean time	$+\ 1^m\ 11^s$	or	$+\ 2^m\ 11^s$
Paris mean time of occultation .	$9^h\ 55^m\ 2^s$	or	$9^h\ 56^m\ 2^s$
Greenwich mean time	$9^h\ 45^m\ 41^s$	or	$9^h\ 46^m\ 41^s$.

The star is B. A. C. 3579.

1686. 1 Juillet. 11 59 16½ |(
1 35)|
0 25 l'ombre a midy.

Juillet 2. 11 59 19 |(
0 26 a l'ombre.
1 36)|

L'horloge occ. retard 1″.

9 19 57 une etoile entre dans lune.
9 37 10 elle s'est sortie.
36 0 elle estoit sortie.

Following this are observations rather difficult to understand, from which it is concluded that midnight on the 2d was at $0^h\ 0^m\ 28^s$; and on the 3d, midy was $0^h\ 0^m\ 34^s\frac{1}{2}$.

Using the correction of the meridian from the observations of June, we have:—

Transit of ☉, July 1, clock .	$0^h\ 0^m\ 21^s.0$;	mean time $0^h\ 3^m\ 9^s.7$.
Transit of ☉, July 2, clock .	$0^h\ 0^m\ 22^s.3$;	mean time $0^h\ 3^m\ 21^s.2$.
Cassini finds, July 2.5 . . .	$12^h\ 0^m\ 28^s$;	mean time $12^h\ 3^m\ 26^s.7$.
Cassini finds, July 3.0 . . .	$0^h\ 0^m\ 34^s.5$;	mean time $0^h\ 3^m\ 32^s.2$.

The clock-correction on mean time seems pretty well determined, and equal to $+2^m\ 59^s$. It seems possible that the clock used was the "horloge occidental", one second slower than the other; but the correction will still be less than $3^m\ 0^s$. We have, therefore:—

Paris mean time of immersion of B. A. C. 5395 (?) . .	$9^h\ 22^m\ 56^s$
Greenwich mean time of immersion of B. A. C. 5395 (?) .	$9^h\ 13^m\ 35^s$.

I shall not attempt to use the emersion.

1689. Mai 18.	53 9	|(
	55 25	)|
	57 23	)| a l'oct.
Mai 21.	52 59	|(
	53 15	)| This time is probably 2^m early.
	9 6 29	l'epy de la ♍ au verticale 31 40 30.
	9 37 2	Imm. d'une etoile de ♊ pres de grimaldi.
	9 59 29½	♄ passe par le vert. du. (?)
Mai 22.	52 52	|(11 54 0½ midy.
	55 9	)|
	55 40	le dernier bord du ⊙ au vert. de l'octant.
	9 2 31	l'epi au vertical.
	9 54 53	arcturus passe par le vert. du quad.

Mai 24.	9 30 42	49 30	30 14	59 46	
	33 1	49 50	27 53	1 4	)| au V.
	35 21	50 10	25 33	2 16	
	9 0 28	l'epy au merid.			
	9 52 46	arcturus au vert.			

Notes on the preceding observations, especially the last:—It is hard to say with certainty what instruments the transit of the sun was observed with. By induction, however, I conclude that the signs |(and)| meant transits of the suns's limbs over the meridian of the octant. But from the observations of May 21, it would seem that this could not have been the case May 22.

The following, however, are transits of ⊙ centre over something, and times of apparent noon from corresponding altitudes:—

		)| |(	Oct.	Quad.	Corresp. alt.
1689. Mai	15.	11^h 54′ 8½″	56^m 6^s		11 54 37
	16.			54 11	
	17.			54 13	
	18.	11 54 17	56 15		
	21.	11 54 7			
	22.	11 54 0½	54 32		
	23.	11 53 56	54 29		
Clock adv. 6^m.	24.	59 56 (?)			0 0 20
	25.	11 59 54½	0 23		
	26.				0 0 24:

The following are the altitudes of the sun for time:—

May 15. a. m.		May 15. p. m.		May 23. a. m.	
9^h 54′ 50″	52° 0′	1 54 41		9 22 13	49 0
57 34	52 20	52 4		24 33	49 20
10 2 58	53 0	46 36		26 53	49 40
5 47	53 20	43 45		29 15	50 0
8 37	53 40	40 55		31 36	50 20

The reduction of these observations has proved troublesome, but I think a pretty certain result may be reached. We have altitudes, singly or in pairs, on the civil dates May 15, 23, 24, and 26. From a separate reduction of the pairs of altitudes, the index-error of the altitude instrument seems to be only 0′.1. The clock-times of apparent noon are thus found to be as in the following table. Comparing them with the times)|, |(, we have the three corrections of the latter:—

Date.	Noon from Alts.	)| and |(.	Corr.	Mean Time.	Clock-correction.
	h m s	*h m s*	*s*	*h m s*	*m s*
May 15	11 54 37	11 54 8.5	+ 28.5	11 55 50	+ 1 13
21	. . .	11 54 7.	. .	11 56 3	1 31
22	. . .	11 54 0.5	. .	11 56 7	1 41
23	11 54 18	11 53 56.	+ 22.	11 56 12	+ 1 54
24	0 0 21	11 59 56. :	+ 25. :	11 56 17	− 4 4

The mean correction to the principal noon-mark being $+25^s$, this quantity is applied to the clock-times of the transits of the sun on the 21st and 22d to obtain the clock-times of apparent noon. The clock-correction for the time of the occultation being $+1^m\ 35^s$, we have:—

Paris mean time of occultation of WEISSE II, 1656 (?) . $9^h\ 38^m\ 37^s \pm 3^s$
Greenwich mean time of occultation of WEISSE II, 1656 (?) $9^h\ 29^m\ 16^s$.

Occultations of 1690, Apr. 13 and July 3.

1690. Apr. 13. $11^h\ 37'\ 52''$ j'ay vu entre la fixe derriere le disque de la Lune par la lunette de 34 p.

The data for clock-corrections are:—

	|(	)|
	h. ′ ″	′ ″
1690. Mar. 24	11 57 48	59 58
25	58 23	0 32
27	57 33	59 41
29	56 21	58 30
30	56 13	58 22
Clock adv. 3′. Apr. 2	59 7	1 17
3	58 48* (?)	— —
5	58 13	0 23
6	57 56	0 6
7	58 3	0 13
8	57 34½	59 44
9	57 10	— —
10	56 43	58 53

Corresponding altitudes ⊙.

	Mar. 24.	
h. ′ ″	h. ′ ″	° ′
10 3 22	1 55 19	37 0
6 42	51 58½	37 20
10 10	48 31	37 40
	April 5.	
9 38 33	2 20 2	38 30
42 21	17 14	38 50
45 13	14 22	39 20
49 32	10 1	39 40
52 29½	7 3½	40 0

April 24.

⊙ per corresponding altitudes without correction . . $58^m\ 45^s$
Interval . . . . . . $5^h\ 45^m$
|(−)| Apr. 23 . . . 11 57 14
25 . . . 11 57 25

* In this and the following observations, it is stated distinctly that the transits are over the vertical of the great quadrant.

Clock adv. 3′. Apr 12	59 6	— —
13	58 40	0 51
15	57 55	0 6
June 11	11 57 41	59 58
13	57 45 (sic)	59 3
14	58 25½ [1]	60 44
15	58 22½	0 41
16	58 21	0 39
July 1	11 59 14	1 30
2	— —	1 28
3	— —	1 31
4	11 59 18	1 35

3 Juillet 3 5 25 une fixe des Pleyades entre dans la lune.

So on Apr. 24 the correction was about + 17^s.

June 13.

h. m. ″	h. ′ ″	° ′
9 50 56	2 8 4	54 20
53 19	5 42	54 40
57 4	1 57	55 20
59 36	59 25	55 30
10 2 6	— —	55 50

June 16.

h. ′ ″	h. ′ ″	° ′
9 22 22½	2 36 48	50 20
24 36	34 32	40
26 52	32 15½	51 0
29 8½	29 58	20
31 25	27 40	40

July 1.

9 27 56	2 32 50	50 50
30 12½		51 10
32 30		51 30
34 47		51 50
37 4		52 10

We have first to find the corrections of the quadrant from the corresponding altitudes. The results are as follows:—

Date.	Noon, from Quadrant.	From Altitudes.	Corr of Quad.
	h m s	m s	s
1690, Mar. 24	11 58 53.	59 3.0	+ 10.0
Apr. 5	59 18.	59 30.8	+ 12.8
Apr. 24	57 19.5	58 31.3	+ 71.8
June 13	58 54.:	59 28.6	+ 34.6
June 16	59 30.	59 32.5	+ 2.5
July 1	60 22.	60 25.1	+ 3.1

We here meet the perplexing question whether these great changes in the position of the quadrant are real, or whether they arise from an accidental error of a minute in the record of April 24, and half a minute in that of June 13. There is clearly an error of one minute in one of the records of transit of the sun's limb on the latter date: I have assumed the error to be in the second limb. But no change in the minutes alone will reconcile the correction with the two following ones. For April 24 I have copied nothing from the original record; the transit of the sun over the quadrant was not observed, but is deduced from those of the days preceding and following. For the corresponding altitudes I took the mean of the actually observed times with the mean interval, the latter being required to compute the correction due to the change in the sun's declination. The remark about the correction being + 17^s

[1] J'avais replacé le grand Q. auparavant l'observation.

I am now quite unable to understand. I have assumed the correction of the quadrant to be $+12^s$ on April 13 and $+3^s$ on July 3–4. Then, we have:—

Date.	Clock-time of Noon.	Mean Time.	Clock-correction.
	h m s	h m s	m s
1690, Apr. 13	11 59 57	0 0 18	+ 0 21
Apr. 15	11 59 12	11 59 47	+ 0 35
July 2	0 0 23	0 3 22	+ 2 59
July 3	0 0 26	0 3 33	+ 3 7
July 4	0 0 29	0 3 44	+ 3 15

We thus deduce:—

	April 13.	July 2.
Clock-corrections at time of occultation .	$+\ 24^s$	$+\ 3^m\ 4^s$
Paris mean times	$11^h\ 38^m\ 16^s$	$15^h\ 8^m\ 29^s$
Greenwich mean times	$11^h\ 28^m\ 55^s$	$14^h\ 59^m\ 8^s$.

The stars are supposed to be 136 Tauri and 27 Tauri.

Assuming the quadrant to have been steady, the probable errors of these times do not exceed two or three seconds. If, however, the corrections to the quadrant on April 24 and June 13 were real, and the instrument correspondingly unsteady, the times may be in error by twenty seconds or more, and are probably too great.

Occultation of Aldebaran, 1699, *Aug.* 18.

Aug. 19, A. M.	1 38 44	l'etoile touche.
	1 39 22	l'etoile entre.
	2 17 12	l'etoile sorte de la lune et paruit grosse.

A correction of $1^m\ 6^s$ is then applied for clock-error; but it is not possible to tell how it was obtained, and the confusion of the observations and of the two clocks is such that the independent computation of a clock-correction is not possible. Here, as in the observations of 1684, we find comparisons between a "horloge orientale" and "horloge occidentale", but no indication as to the clock with which any particular observation was made.

In examining the observations 1686–1690, I find no indication that more than one clock was used.

The last volume of the series from which the preceding observations are copied, viz, vol. 19, is in a much nicer handwriting, and is evidently not a simple record of observations, but a mixture of observation and calculated results. An occultation of Aldebaran was observed 1701, February 16, but it is hard to tell what is meant.

The duplicate series is bound in vellum, and is evidently a simple copy of the preceding in a fairer handwriting. As the copy seemed to be quite correct, and to include everything, I have sometimes employed it to copy from, nearly always, however, comparing with the original as I went along. This series is numbered 1009, and is bound in vellum. Vol. 1 is missing; at least, I could not find it. Vol. 2 commences with 1682, January 1, but has no title whatever. On the inside of the cover of each volume is a rude index to the principal observations. The series continues without interruption to 1795, but a number of volumes are missing.

From the last described series, vol. 9.

Eclipse of 1724, May 22?

Observations faites par SAREL (?) dans tour inferieure occidentale.

5	55	24	com. decl.
6	49	10	Totale.
	51	52	recouv. de lum.
	57	40	On ne vcit plus le soleil.
7	39	0	pend. sup.
7	39	26	pend. inf.

Observation faite par M. DES PLACES avec une lunette de 34 pieds par le moyen de l'image du soleil que se peignoit sur un papier . . . . avec une montre de poche mis sur l'heure de la pendule a demie second.

	5	56	0	comm. par estimation.
(sic)	6	48	20	Totale.
(sic)		51	5	recouvr. de lumière.

Imm. dans l'ombre 2^m 35 sec. (sic). Cette eclipse a été observée a Trianon.

A l'observatoire par M. GAUDIN.

5	55	16	comm.
6	48	51	Immersion.
	51	13	recouv. de lumière.

A Trianon en presence du Roy.

5 54 50 commencement de l'eclipse.
48 24 eclipse total qui arriva dans un instant.
50 40 recouvr. de lumière qui parut comme un eclair. la pendule avancé de 20″ et Versailles est plus occidentale que paris de 52″ et trianon est encore a l'occid. de quelques secs.

All this is a literal copy from the record.

The transits of the sun were as follows :—

		☉ I		I ☉	
Mai 21	11	56 28		58 44	3′ adv. à la pend. superieur.
22		59 22½	Douteux.	1 39	Bon.
23		59 15	a peu pres.	1 36	
24		59 23		1 37	
25		59 19		1 35	
26		59 19		1 31	

There are no altitudes till December 30, and then, it would appear, only because something had happened to the quadrant.

From this point onward, the observations are made and recorded too carelessly to be of any use.

Eclipse of 1715, May 2.8.

3 May.	6^h	51′	0″	pend. sup.
	6	50′	54″	pend. inf.
ad. 14″	8	13	0	comm. de l'Eclipse. lunette de 8 pieds, pend. inf. et lunette de 34 pieds.
	8	27	30	3 Doits
		37	20	5 d. ½
		41	30	6
		45	50	10 d. ½ (sic)
	9	18	15	11¼
		20	12	11
		40	50	11
		53	0	6
	10	11	30	4

17 16 3
23 0 1
28 30 Fin observeé a lunette de 8 pieds.
12 33 0 pend. sup.
32 55 pend. inf.

Observation faite a Marly. (Record in the same hand, and that a good one.)

Le 2. May a 9^h 14′ 6″ H. d. Arcturus 51 40
9 19 10 52 20
Le 3. May a 6 40 52 H. du ⊙ 18 30
a 8 11 32 Commencement vu avec une lunette de 8 pieds.
8 16 10 Un doit. Le pendule a avancé de 30″ qu'il faut retrancher de [toutes les observations.
20 58 2
26 49 3
29 54 4
33 0 Quatre doits
38 7 Cinq.

[Omitted copying the rest of the observations. They are found printed in the Memoirs for 1715.]

10^h 28′ 20″ Fin, que l'autres personnes ont jugeés a 10^h 28′ 0″
10 34 59 H. du ⊙ 52 40.

Le Roy a assisté aux observations qui se sont faites vers le milieu et a la fin aussy bien que M. le Duc d'Orleans et toute la cour qui y . . . pendant presque toute la dureé de l'Eclipse.

At the end of the volume is given the calculation of clock-error from the four observed altitudes. A. R. Arcturus, 210° 42′ 35″; of ⊙ at noon, 38° 55′ 33″; at time of observation, 39° 17′ 36″. Altitude, 51° 40′ 0″ − 48″ = 51° 39′ 12″; φ = 90° − 41° 8′ 25″; H = 32° 38′ 24″ &. 31 22 54; set. deh 0′ 57″ (?) 0 58″ (?).

J'ay avancé la pend. d'une minute.

Next morning clock-errors − 37″ & − 28″. N. P. D. Arcturus 69° 19′ 8″.

There is no clue to the place where or the person by whom the first of the above set of observations was made, except the clock-error, which agrees with one determined at the Paris Observatory. The second set, made at Marly (now Marly-le-Roi), agrees, so far as I copied it, with the printed observations in the *Mémoires* The presence of the monarch probably exerted a very injurious effect on the observations, and I have been in some doubt whether they are worth using.

For clock-correction at Paris.

1715. May 1. A. M. 8 5 16 pen. inf. = 8 11 0 pen. sup., Diff. 5′ 44″.

1 11 59 26 (1 38)
2 59 21 1 33
3 59 18 1 30

Now comes this calculation:—

11 59 18
1 6
———
12 0 24
33
———
11 59 51 midy pend. sup.
11 59 46 midy pend. inf.
———
14″ a ad.

4 May. 11 59 18 (1 30)

May 1.
H. d'Arcturus.

8^h 8′ 42″		41^d 20′
8 22 33		43 30
8 25 42		44 0
8 29 0		44 30
8 32 15		45 0
8 35 36		45 30
8 38 52		46 0
8 42 15	epy	26 20
46 5		26 40
9 46 4	le petit chien	13 30
59 9		13 0
2 12		12 30

The record gives no means of judging which clock was used in observing the altitudes, or when the pend. inf. was put back.

The coincidence of clock-errors leaves no doubt that we here have the clock-correction for the unidentified observation at the Paris Observatory. I make the correction for quadrant — 39^s instead of — 33^s, and find, for the correction to reduce the "*pend. inf.*" to mean time, — $3^m\ 2^s$. This will make the time of beginning 58^s later than that observed by La Hire and the others, a quantity so great as to lead to the suspicion of a mistake of a minute in the record. The end agrees well with that observed by the La Hires. The observations of digits are too wild to merit consideration, and altogether it does not seem worth while to make any further use of these observations.

Series II.

Observations of La Hire.

In this series of observations, the clock-errors are more carefully determined than in the case of the observations of the Cassinis. Occultations are found only in a few widely scattered years between 1682 and 1718, but the times are so well determined that they seem to compare favorably with modern occultations in precision. The transits of the sun, and occasionally of stars and planets, are observed over some meridian instrument which does not seem to have been disturbed while La Hire used it. The following are the corrections necessary to reduce the times of transit over the instrument to those over the true meridian as derived from the corresponding altitudes of the sun, which are found in the following pages:—

Date.	Clock-time of Transit of ⊙ over Merid. of Instrument.	Mean Clock-time of Corres. Altitudes.	Mean Interval.	Corr. for Mot. of ⊙.	Transit of ⊙ over True Meridian.	Corr. of Merid. Instrument.	Dec. of ⊙.
	h m s	h m s	h m	s	m s	s	° ′
1684, July 10	12 5 23.6	12 5 32.8	8 50	+ 6.0	5 38.8	+ 15.2	+ 22 15
Dec. 19	12 9 43.8	12 9 28.2	6 22	+ 0.3	9 28.5	— 15.3	— 23 26
1685, Feb. 13	12 6 28.0	12 6 32.0	6 32	— 19.0	6 13.0	— 15.0	— 13 .
May 28	11 58 50.0	11 59 9.9	7 13	— 6.6	59 3.3	+ 13.3	+ 21 26
July 16	0 0 7.8	0 0 12.2	11 0	+ 9.8	0 22.0	+ 14.2	+ 21 25
Sept. 14	0 4 58.6	0 4 30.4	8 54	+ 20.9	4 51.3	— 7.3	+ 3 29
Oct. 10	0 2 2.9	0 1 28.6	8 16	+ 21.3	1 49.9	— 13.0	— 6 35
Oct. 27*	. . .	. . .	. .	. .	. .	— 16.2	— 13 .
Nov. 27*	. . .	. . .	. .	. .	. .	— 15.2	— 21 .
1699, June 2*	0 2 1.8	. . .	. .	. .	2 20.0	+ 18.2	+ 22 .
Aug. 21	0 1 4.0	0 0 52.3	7 27	+ 15.3	1 7.6	+ 3.6	+ 12 22
Sept. 12	11 58 4.5	11 57 42.0	7 1	+ 18.7	58 0.7	— 3.8	+ 4 27
Oct. 23	0 0 17.2	11 59 41.6	8 34	+ 20.7	0 2.3	— 14.9	— 11 11
1706, May 6	0 0 16.5	0 0 39.6	8 31	— 13.5	0 26.1	+ 9.6	+ 16 26
1708, Sept. 16	11 58 38.0	11 58 9.7	8 49	+ 21.0	58 30.7	— 7.3	+ 2 37
1715, May 9	11 58 26.0	11 58 49.2	9 20	— 13.5	58 35.7	+ 9.7	+ 17 .

* For these three dates, I have accepted La Hire's reduction of his corresponding altitudes, as his reductions were found in other cases to be correct.

We now arrange these corrections according to the sun's declination, putting in a separate column those determined after the interval of 14 years between 1685 and 1699. We find them to be as follows:—

⊙'s Dec.	1684–5.		1699–1715.	Formula.
°	s	s	s	s
− 23	− 15.3		.	− 15.7
− 21	− 15.2		.	− 16.1
− 13	− 15.0	− 16.2	.	− 14.9
− 11	.		− 14.9	− 14.1
− 7	− 13.0		.	− 12.6
+ 3	− 7.3		− 7.3	− 6.6
4	.		− 3.8	− 5.7
12	.		+ 3.6	+ 2.7
16	.		+ 9.6	+ 8.0
17	.		+ 9.7	+ 9.0
21	+ 13.3	+ 14.2	.	+ 15.1
22	+ 15.2		+ 18.2	+ 16.6

There seems to be no evidence of any change in the instrument during the whole period of the observations. Supposing the axis on which it turned to be quite true, so that its deviation from the meridian arose only from errors of level, collimation, and azimuth, the correction necessary to reduce the time of transit of an object over it to the true meridian could be expressed in the form

$$m + c \sec \delta + n \tan \delta,$$

δ being the declination of the object. The values of the constants which best represent the above deviations are:—

$$m = -\ 121^s.4$$
$$c = +\ 112^s.7$$
$$n = +\ \ 39^s.8.$$

The numbers computed from these values of the constants are given above in the last column. They seem to represent the observed deviations within the probable errors of the observations. The following table shows the corrections computed from the formula:—

Decl.	Corrections.	Diff.
°	s	s
− 25	− 15.8	
		− 0.1
− 20	− 15.9	
		+ 0.6
− 15	− 15.3	
		1.3
− 10	− 14.0	
		2.2
− 5	− 11.8	
		3.1
0	− 8.7	
		3.9
+ 5	− 4.8	
		4.8
10	0.0	
		5.9
15	+ 5.9	
		7.0
20	+ 12.9	
		+ 8.7
25	+ 21.6	

We shall use this table in reducing transits to the true meridian in order to obtain clock-corrections.

Extracts from LA HIRE'S *Journal.*

Vol. 93, page 4.—LA HIRE'S first occultation, observed at Observatory.

1682, Feb. 15. ☉.

Mane.		Vesper.	
9 1 49	17 30	2 58 40	Correct. 37½. Il étoit donc midy a 11 59 55.
9 6 4	18 0	51 23½	
9 10 24	18 30	50 2	

Le 17 a midy l'horloge devoit se tarder de 37.

From altitudes of Cauda Leonis it seems the clock lost $28^m\ 52^s$ on sidereal time between February 10 and 17, or 11″½ a day on mean time.

The following are the altitudes on the 17th:—

1682. Feb. 17.	9^h 4′ 6″	Alt. = 28° 30′
	7 11	29 0
	10 15	29 30
	13 22	30 0

Eclipse of Hyades par la lune Feb. 15.

Doub. *	6 59 2	Emersion of *a.*	According to LE MONNIER, *Hist. Coeleste* p. 257, the
	7 1 27	" *b.*	apparent times were 6 59 12, 7 1 37.

The corresponding altitudes of the sun give:—

Clock-time of ☉'s transit	$23^h\ 59^m\ 54^s.9$,
While mean time of ☉'s transit is	$0^h\ 14^m\ 41^s.7$.
Clock-correction	$+ 14^m\ 46^s.8$.

The clock-rate being 11^s 5 per day, the error at the time of occultation would be $+ 14^m\ 50^s.2$. As a check upon the rate, I have computed the correction from the altitudes of β Leonis on February 17, and found, as the mean result from the four altitudes:—

Feb. 17, $9^h\ 9^m$ clock-time; correction $= + 15^m\ 10^s.5$.

This gives a rate of 10^s per day, and a correction at the time of occultation $0^s.4$ less than that found above. I have, however, used $+ 14^m\ 50^s.2$, giving:—

	θ^1 Tauri.	θ^2 Tauri.
Paris mean times of occultation . .	$7^h\ 13^m\ 52^s.2$	$7^h\ 16^m\ 17^s.2$
Greenwich mean times of occultation	$7^h\ 4^m\ 31^s.2$	$7^h\ 6^m\ 56^s.2$.

The equation of time being $+ 14^m\ 40^s.8$, these results do not differ one second from those given by LE MONNIER. The phase is actually immersion, not emersion.

☉ *Eclipse*, 1684, *July* 12.

Manuscript, vol. 93, page 287.—Observations of LA HIRE.

10 Julij.

Altitudines superioris Limbi ☉ pro horolog.

Mane.			
7 32 54½	31° 0′		
35 58	31 30	35′ 8″	Correctio 12½ addenda.
38 59	32 0	32 5½	
42 3	32 30	29 2	
45 5½	33 0	4 25 59½	

Meridies horologio indicante	12^h	5′	38″½
⊙ Transitus prioris Limbi	12	4	15¼
Transitus posterioris Limbi	12	6′	32″
		2	16¾
Transitus centri	12	5	23⅝
Transitus per. ver Meridianum	12	5	37
♀ Transitus centri	3^h	6	32½
Transitus veri Temp. per verum Merid.	3	0	55
♃ Transitus Centri	4^h	1′	8″

11 Julij.

⊙ Transitus prioris Limbi	12^h	4′	19″
Transitus posterioris Limbi	12	6	35¼
		2	16¼
Transitus centri	12	5	27⅛
Altitudo Merid. superioris Limbi	63	27	50
N Serpentarii Transitus	9	30	54½
et tardavit (?) horologium pro duobus diebus			10″½

12 Julij.

Altitudines superioris Limbi ⊙ pro horolog.

Mane.

5	36	5	21°	30′
	39	8½	22	0
	42	14	22	30
	45	18½	23	0

Vespere Eclipsis Solaris.

Phases.	Tempus.	Phases.	Tempus.
29′ 56″	2^h 35′ 59″	11′ 5″	3^h 45′ 49″
27 51	41 49	12 45	56 49
27 13	43 59	13 45	4 2 29
24 55	49 59	14 39	6 9
23 36	53 49	16 14	10 49
22 4	57 29	19 32	19 39
19 55	3 3 49	21 23	24 19
17 56	9 59	23 36	30 39
16 14	16 29	26 46	37 39
14 1	23 49	29 37	44 19
13 4	27 9		
11 48	34 9	Initium 2 31 6	tempore horolog.
11 0	42 9	5 42½	corr. horol. subt.
		2 25 23½	temp. vero.

Chordae.	Tempus.	Chordae.	Tempus.
13′ 30″	2^h 38′ 19″	27′ 15″	4^h 8′ 16″
17 5	45 49	23 55	22 19
21 15	55 9	22 20	26 39
22 50	3 0 19	19 5	34 0
25 49	7 49	12 45	43 9
26 27	13 34		
27 13	19 19		
28 34	29 39		
29 37	37 39		
28 24	59 19		

Finis totius Eclipseos, $4^h\ 49'\ 9''$.
Pars illuminata $17'\ 44''$. $4^h\ 14'\ 49''$ Diam. Lunae $29'\ 39''$.
Horologium accelerabat tempore Eclipseos $5'\ 42''\frac{1}{2}$.
Fuit igitur finis veri temporis $4^h\ 43'\ 26''\frac{1}{2}$.

13 Julij.

Altitudines superioris Limbi ⊙ pro horologio.

Mane.			
8 33 12	$40^\circ\ 30'$	3 38 5	Correctio addenda $12''$.
36 19	41 0	34 58	
39 $28\frac{1}{2}$	41 30	31 49	
42 37	42 0	28 40	

In meridie sole existente, horolog. indicavit 12 5 $44\frac{1}{2}$.

The clock-corrections for this eclipse are derived as follows:—

Date.	Clock-time of Noon.	Mean Time.	Clock-correction.
1684.	*h* *m* *s*	*h* *m* *s*	*m* *s*
July 10	0 5 40.0	0 4 44.1	— 0 55.9
11	0 5 42.3	4 52.8	— 0 49.5
13	0 5 44.3	5 8.6	— 0 35.7

The single altitudes observed on the morning of July 12 could be made available for determining the clock-correction on that day; but the rate of the clock is so good that I have not deemed it necessary to go through the labor of discussing them. Interpolating between July 11 and 13, we find for the clock-error, before and after the eclipse:—

July 12, $2^h.1$ . . . . Clock-correction, $-42^s.0$.
July 12, $5^h.3$ . . . . Clock-correction, $-41^s.0$.

Occultation of μ Geminorum, 1684 December 21.

19 Decembris Mane ♍ Transitus . . . . $7^h\ 25'\ 7''$

Alt. ⊙ sup. limbi pro horolog.

Mane.		Vespere.	
$8^h\ 53'\ 55''$	$6^\circ\ 0'$	$25^m\ 2^s$	$1''$ correctio add.
56 54	6 20	22 2	
59 55	6 40	19 2	
9 2 57	7 0	3 15 59	

Centrum ⊙ transivit per merid. indicante horolog. . . . . . . 12 9 $28\frac{3}{4}$
♀ Transitus centri . . . . 9 6 $55\frac{1}{2}$
⊙ Tran. prior. limbi 12 8 33
" posterioris " . . . . 10 $54\frac{1}{2}$
" centri . . . . 12 9 $43\frac{3}{4}$
Ceti os. transitus 9 0 1
Aldebaran " 10 31 37
☽ I " 10 33 46

20 Decembris.
Retroactum est horolog. 10′.

⊙ transitus I	11	59	0
" " II	12	1	22
Cent.	12	0	11

21 Decembris.

Ceti os. transitus 8 42 4.
Pro duobus diebus tardavit horolog. 5″.
Inter 21 et 22 in media nocte accelerav horol. 33″.
Accelerae hor. in media nocte 37″.

Vespere.

Occultatio stellae μ II a ☾ parte eclipsata	9	35	23	
Emersio vel appar. ejus ✳	10	9	2	
Transitus ☽ I	12	1	44½	2 16
II	12	4	0½	1 8

22 Decembris.

⊙ I	11	59	53½
⊙ II	12	2	16
Cent.	12	1	4¾

The clock-corrections derived from the transits of the sun from December 19 to 22, and those of the moon and α Ceti on the 21st, are shown in tabular form below. The first transit of the sun is that derived from the corresponding altitudes. The tabular right ascension of the moon probably requires an increase of two seconds of time; this correction has therefore been applied to its tabular right ascension at the time of transit to obtain the mean time of transit.

Date.	Object.	Clock-time of Transit over Meridian Instrument.	Corr. for Deviation.	Clock-time of Transit over True Meridian.	Computed Mean Time of Transit.	Apparent Clock-correction.
1684.		h m s	s	m s	m s	m s
Dec. 19	⊙ . . .	0 9 43.8	− 15.9	9 28.5*	58 19.3	− 11 9.2
20	⊙ . . .	0 0 11.0	− 15.9	59 55.1	58 49.4	− 1 5.7
21	α Ceti .	8 42 4.	− 6.3	41 57.7	40 53.8	− 1 3.9
21	Moon . .	12 2 52.5	+ 17.0	3 9.5	2 6.0	− 1 3.5
22	⊙ . . .	12 1 4.8	− 15.9	0 48.9	59 49.8	− 0 59.1

The occultation was observed between the transits of α Ceti and the moon. The agreement of the clock-corrections and the uniformity of the rate seem to indicate that the times can be determined within a second. Deriving the clock-correction from the transits of α Ceti and the moon, we have:—

	Immersion.	Emersion.
Clock-corrections for occultation of μ Geminorum . .	$-1^m\ 3^s.8$	$-1^m\ 3^s.7$
Paris mean times	$9^h\ 34^m\ 19^s.2$	$10^h\ 7^m\ 58^s.3$
Greenwich mean times	$9^h\ 24^m\ 58^s.2$	$9^h\ 58^m\ 37^s.3$

* From the corresponding altitudes.

1685, Feb. 13.

Altitudines sup. limb. ⊙ pro hor.

Mane.		Vespere.	
8h 46′ 14″	14° 20′	26′ 51″	
48 53	14 40	24 10	Correct. subt. 38″.
51 34	15 0	21 29	
54 17	15 20	18 48	

Solis cent. tetigit meridianum, indicante hor. 12 6 13.

⊙ transitus I 12 5 21

II 7 35

Centri 12 6 28

On 1684, Dec. 2, the transit of ⊙ was 14½″ late, so that there can be no doubt of the correction to LA HIRE's gnomon.

Here there is a lacune in DELISLE's copy of LA HIRE, from which the preceding is copied; this lacune is afterward filled up from LA HIRE's original.

1685. For correction of LA HIRE's meridian.

A. M.		P. M.			
	May 28				
8 17 50	39 0	3 40 29	13½″ corr. subt.	⊙ Tr.	11 57 42
20 57	39 30	37 22½			11 59 58
24 4	40 0	34 16			
27 11½	40 30	31 9			11 58 50
				over mer.	11 59 3
					+ 13″
	July 16.				
6 20 56	19 30	5 39 26	21″ add.	⊙ Tr.	11 59 0½
24 2	20 0	36 21			12 0 16
39 30	22 30	20 58	19″ add.		
					12 0 7¾
	Sept. 14.				
7 32 34	17 0	4 36 26	42″ add.	Sept. 13 ⊙	19 4 26
35 45	17 30	33 16			12 6 34
38 56	18 0	30 6			
42 6	18 30	26 55	41″ add.		12 5 30
				per m.	5 21½
					8½
	Sept. 13.				
7 18 42	15 0	4 51 18	43″ add.	Sept. 16 ⊙	12 2 51½
					5 0
					12 3 55¾
	Oct. 10.				
7 48 21	12 0	4 14 38	+ 43″	Oct. 9, ⊙ tr.	12 1 22½
51 44	30	11 13			3 32
55 10	13 0	7 45	+ 42″½		
58 35	13 30	4 23			12 2 27¼
				Oct. 11. ⊙ tr.	12 0 32½
					2 42½
					12 1 37½

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Immersio stellae H Geminorum, 1685, Oct. 17. 9 52 29 Pend.

Oct. 16	⊙ cent. transit	11	59	38	
17	Scheat Pegasi tr.	9	14	11	
	Markab.	9	15*	57	[* LE MONNIER prints 14, which is right, but it is clearly 15 in the MS.]
18	α Aquilæ	5	57	45	
	Scheat Peg.	9	10	5	
	Markab.	9	10	51	
20	⊙	11	58	16.6	
27	Correction of quadrant per ⊙			$-16^s\frac{1}{4}$.	
Nov. 27	" "			$-15^s\frac{1}{4}$.	

The clock-corrections from 1685, October 16 to October 20, are derived from the observations as follows:—

Date.	Object.	Dec.	Corr. for Deviation.	Clock-time of Transit over True Meridian.	Computed Mean Time of Transit.	Apparent Clock-correction.	C'.	△.
1685.		°	s	h m s	h m s	m s	s	s
Oct. 16	. . .	− 9.3	− 13.8	11 59 24.2	23 45 31.2	− 13 53.0	53.0	0.0
17	β Pegasi .	+ 26.3	+ 23.9	9 14 34.9	9 0 48.5	− 13 46.1	39.2	− 7.2
	α Pegasi .	+ 13.5	+ 4.0	9 15 1.1	9 1 20.4	− 13 40.7	39.2	− 1.5
18	α Aquilæ.	+ 8.1	− 1.9	5 57 43.1	5 44 14.4	− 13 28.7	30.5	+ 1.8
	β Pegasi .	+ 26.3	+ 23.9	9 10 28.9	8 56 52.0	− 13 36.9	29.2	− 7.7
	α Pegasi .	+ 13.5	+ 4.0	9 10 55.0	8 57 23.9	− 13 31.1	29.2	− 1.9
20	⊙ . . .	− 10.7	− 14.2	11 58 2.4	23 44 49.4	− 13 13.0	13.0	0.0

The discordance of clock-errors is perplexing. There is a seemingly systematic difference of nearly six seconds between the corrections from α and from β Pegasi. As the latter lies without the limits between which the deviation of the instrument was determined, the corresponding result is to be received with suspicion. If we determine the clock-correction and rate from the transits of the sun on the 16th and 21st, we have the results in columns c' and △, the latter being the difference between the computed error and that derived from the intermediate observations. The most probable value of △ for the time of the occultation may be estimated at $-1^s.0$, with a probable error of 2^s. This will give for the occultation of H Geminorum:—

Clock-correction	$-13^m\ 40^s.0$
Paris mean time of the occultation, October 17 .	$9^h\ 38^m\ 49^s.0$
Greenwich mean time of the occultation	$9^h\ 29^m\ 28^s.0 \pm 2^s$.

Mane, 19 August 1699.

Immersio Aldebaran $1^h\ 41^m\ 36^s$

Emersio 2 19 37.

Sed etiam in momento apparuit magna et in disco ☾ reflexione luminis terrae illustratae.

The observed transits of ⊙ were:—

	I.	II.	Cent.
Aug. 15	11 57 38	59 $48\frac{1}{2}$	58 $43\frac{1}{4}$
17	58 23	0 33	59 28
18	58 43	0 54	59 $48\frac{1}{2}$
21	59 59	2 9	1 4
A. M. Aug. 19 ♄			0 14 17

Aug. 21. Altitudines ⊙ pro horolog.

8 11 1	30 30	3 50 43½	
14 14	31 0	47 30	
17 28	31 30	44 18	Corr. 31″.
20 39½	32 0	41 4½	
23 50	32 30	37 48	

Centrum ⊙ pervenit ad Circulem meridianum indicante horologio $12^h\ 1'\ 7''\frac{1}{2}$.
Quare tardat quadrans muralis in altitudinem $53^\circ\ 12'$ . . . . $3\frac{1}{2}''$.
On the 2d June preceding, he found a correction to the quadrant of $+18''\frac{1}{4}$, as follows:—

⊙ Transit	June 1,	0 1 48
	5,	0 2 55
Debui transire	" 2,	0 2 1¾
Transit per alt. coresp.		0 2 20
Corr		+18¼

Again, Sept. 12, the correction was $-4''$. The change probably depends on the sun's Z. D.

The derivation of clock-corrections from transits of the sun is as follows:—

Date.	Dec.	Corr.	Clock-time of Transit over True Meridian.	Mean Time.	Corr. of Clock.	Hourly Rate.
1699.	°	s	h m s	h m s	m s	s
Aug. 15	+ 14.0	+ 4.7	11 58 47.9	0 3 55.9	+5 8.0	1.42
17	13.4	4.0	59 32.0	0 3 31.8	3 59.8	1.37
18	13.0	3.4	59 51.9	0 3 18.9	3 27.0	1.62
21	12.0	+ 2.2	61 7.2	0 2 37.5	1 30.3	

In obtaining the time of the last transit, double weight has been given to the result from equal altitudes. Interpolating between the last two corrections, we have, for the times of phases:—

	Immersion.	Emersion.
Clock-correction	$+\ 3^m\ 4^s.8$	$+\ 3^m\ 3^s.8$
Paris mean time, 1699, August 18 .	$13^h\ 44^m\ 40^s.8$	$14^h\ 22^m\ 40^s.8$
Greenwich mean time	$13^h\ 35^m\ 19^s.8$	$14^h\ 13^m\ 19^s.8$.

23 Sept. ⊙ Eclipsis, 1699, mane.

Initium	$8^h\ 13'\ 18''$	Dig. 8 30	9 41 39
Dig. 0½	15 43	8 0	45 37
1	18 28	7 30	49 27
1½	22 19	6 30	55 42
2	25 30	6 0	10 0 16
2½	28 44	5 30	4 13
3	30 46	5 0	9 5
3½	34 19	4 30	12 47
4	37 6	4 0	15 55
4½	40 4	3 30	19 6
5	43 16	3 0	23 5
5½	46 55	2 30	27* 4

* It seems as if the minutes first recorded were 26, and that they were afterward changed to 27. There is no evidence to show with certainty whether this was simply to make the differences run more smoothly or not. The change was evidently made after taking the differences.

Dig. 6	8^h 50′ 28″
6½	54 2
7	57 23
7 30	9 1 20
8	5 11
8 30	9 12
9	14 6
9 30	21 21
Maxima obscuritas.	
9 30	28 57
9 0	35 53

Dig. 2 0	10 30 26
1 30	33 53
1 0	37 19
0 30	39 57
finis	43 18

Diameter ⊙ cum micrometro 31′ 58″.

Tempore observationis horolog. tardebat 1′ 41″.

	⊙ tr. I.	II.	Cent.
Sept. 12	11 57 0	59 9	58 4½
13	56 35	58 43	57 39
11	57 27	59 39	58 31
20	58 30½	0 38½	59 34½
21	. .	0 16½	59 11½
22	57 45	59 52½	58 48¾
23	57 20½	59 29	58 24¾
26	56 8	58 17	57 12½
Oct. 22	59 8½	1 20½	0 14½
23	59 11	1 23½	0 17¼
24	59 14	1 26	0 20

Oct. 23 Cent. ⊙ tr. per mer. circ. ind. horol.
12 0 1½

Sept. 12.
Altitudines ⊙ pro horol. et quadrantis muralis deviatione.

8^h 12′ 53″	25° 0′	42′ 30″	
22 58	26 30	32 26	
26 20	27 0	29 3	36¾
29 47½	27 30	25 37	
33 15	28 0	22 9	
36 44	28 30	3 18 42	

Oct. 23.

7 37 20	7° 0′	22 2
40 46	7 30	18 36½
44 15	8 0	15 7
47 45	8 30	4 11 41

Corr. 40½ add.

Quamobrem auferendum in haec altitudine ⊙ 15″¾ a transitu ⊙ centre per quadrantem muralem.

The clock-corrections are derived thus :—

Date.	Clock-time of Transit.	Mean Time of Transit.	Clock-correction.
	h m s	*h m s*	*m s*
1699. Sept. 20	23 59 26.2	23 53 9.3	− 6 16.9
21	59 3.0	52 48.6	− 6 14.4
22	58 40.0	52 28.0	− 6 12.0
23	58 15.8	52 7.5	− 6 8.3
26	57 2.8	51 7.0	− 5 55.8

The correction for the time of the eclipse is $-6^m\ 9^s$.

1701, 23 Sept. (mane).

Aldebaran occultata a Luna 6 10 50
6 7 0 veri temp.

Notandum quod stella jam supra discum Lunae quantitatae 1½ diametri suae apparebat quando omnino evanuit, et circiter post 2″ temporis centri stellae immersionis apparentis.

(A similar remark was made on the other occultation.)

Emersio . . 6 57 8
Veri temporis 6 53 18. L'horloge tarde de 35″ par jour.

There are no corresponding altitudes given since those of Oct. 23, 1669, but he seems to know the errors of his quadrant e. g.

20 Sept. 1701 ♀ centri Transitus per Quad. mur. $11^h\ 7'\ 42''$.
Transitus per Q. M. veri temporis 11 2 12½ altitudo ver. 50° 11'.
Transitus per v. merid. ver. temp. 11 2 12.
On the same day we find :—
Transitus centri ⊙ per vero merid. 12 5 28, indicating a correction of $-6''$.

	⊙ tr. I.	II.	Cent.	
1701, Sept. 19	12 5 7½	7' 16''	6 11¾	Sept. 23 per ver. merid. 12 3 41.
20	4 30	6 38	5 34	
21	3 35	6 3	4 59	
23	2 43	4 51	3 47	
24	2 8	4 16	3 12	

There are no altitudes within the two years following, and no explanations of the data for deviation of the mural quadrant.

The clock-corrections, as derived from the transits of the sun, are:—

Date.	⊙'s Dec.	Corr.	Clock-time of Transit over True Meridian.	Mean Time of Transit.	Clock-correction.	Hourly Rate.
1701.	°	s	h m s	h m s	m s	s
Sept. 19	+ 1.6	− 7.5	0 6 4.3	23 53 40.2	− 12 24.1	
						0.72
20	+ 1.2	− 7.8	5 26.2	53 19.4	− 12 6.8	
						0.60
21	+ 0.8	− 8.1	4 50.9	52 58.6	− 11 52.3	
						0.66
23	+ 0.1	− 8.7	3 38.3	52 17.5	− 11 20.8	
						0.62
24	− 0.3	− 8.9	3 3.1	51 57.1	− 11 6.0	

Interpolating to the time of occultation, we have:—

	Immersion.	Emersion.
Clock-correction for time of phase	$-11^m\ 24^s.7$	$-11^m\ 24^s.2$
Paris mean time, Sept. 22	$17^h\ 59^m\ 25^s.3$	$18^h\ 45^m\ 43^s.8$
Greenwich mean time	$17^h\ 50^m\ 4^s.3$	$18^h\ 36^m\ 22^s.8$.

1706, ⊙ Eclipsis, 12 Maii, mane.

Initium circa $8^h\ 25^m\ 0^s$ nam hora 8 25 10 jam apparebat Eclipsis quam proxime ⅛ digit quod ad visum per tubum patebatur.

Postea nubes frequentissimae nullas observationes habere permisserunt usque ad horam $8^h\ 48'$. Observationes sequentes habitae sunt horologio ut se habet et non correcto.

$8^h\ 48'\ 0''$	19' 59''	9 54 45	11 24
52 0	17 49	56 10	12 2
55 0	16 33	57 45	12 45
57 35	15 17	59 30	13 23
9 0 20	14 1	0 50	14 0
1 10	11 24	2 25	14 39
7 15	10 46	3 45	15 17
8 40	10 8	5 15	15 55
9 55	9 30	6 45	16 33

Transits of ⊙.

May 4	11 59 37	1 49	12 0 43
5	—	1 35½	0 29½
6	59 10	1 23	0 16½
7	—	1 10	0 3½
8	58 46	0 59	59 52½
9	58 36	0 48½	59 42¼
10	58 23	0 36	59 29½

9h 11′ 10″	8′ 52″	8 25	17 11
12 40	8 14	9 45	17 48
14 10	7 36	11 20	18 26
15 32	6 58	12 50	19 5
17 10	6 20	14 0	19 43
18 33	5 42	14 55	20 21
20 25	5 4	16 10	20 59
22 5	4 26	17 55	21 37
24 5	3 48	19 8	22 15
26 5	3 10	20 50	22 53
31 0	2 45	22 15	23 31
34 15	3 10	25 15	24 47
36 15	3 48	26 25	25 30
38 26	4 26	27 52	26 8
40 0	5 4	29 10	26 46
41 38	5 42	30 20	27 24
43 0	6 20	31 32	28 2
44 40	6 58	33 5	28 40
46 20	7 36	34 36	29 18
47 30	8 14	36 5	29 56
49 5	8 52	37 40	30 34
50 25	9 30	40 24	finis eclipsis accurate.
52 0	10 8		
53 30	10 46		

May 11	11 58 10	0 24	12 59 17
12	—	0 13	59 6
14	57 43	59 56	58 49½

6 Maii pro meridie determinando altitudines ⊙.

h ′ ″	° ′	
7 37 36	28 30	23 44
40 41	29 0	20 38
43 42	29 30	17 36
46 49	30 0	14 30
49 54	30 30	11 27
52 58½	31 0	4 8 20

Centrum ⊙ tr. ind. horol. 12 0 26.

Tempore eclipsis tardabat horologium 42″.

The results for clock-error, as derived from the transits of the sun, are as follows:—

Date.	Clock-time of Transit.	Mean Time of Transit.	Clock-correction.
1706.	h m s	h m s	m s
May 10	23 59 39.0	23 55 59.5	— 3 39.5
11	59 26.8	55 56.8	— 3 30.0
12	59 16.2	55 54.7	— 3 21.5
14	59 0.4	55 52.1	— 3 8.3

The resulting clock-correction at the beginning of the eclipse is $-3^m\ 22^s.7$, and at the end $-3^m\ 21^s.9$.

1708, 23 Februarii.

⊙ tran. I	11 59 8		
II	12 1 21	♀ Eclipsis a ☾ Initium	7 3 47
Cent.	12 0 14½	Veri Temporis	7 3 48
pro merid.	12 0 1	Finis	7 3 57
			7 3 58

Feb. 24.

⊙ trans. I	11 59 2
II	12 1 13
Cent.	12 0 7½
pro merid.	11 59 54

1708, Sept. 14. mane. Eclipsis ⊙.

In media eclipsis horologium tardabat ex tempore vero 35″ sed correcto postea tempore per novas observationes tardabat 37″.

In sequentibus phasibus tempus verum notatum est. Sed addendum praeterea 2″ propter novas correctiones quadrantis. Initium non fuit observandum propter nubes.

Hora vera.	Diameter residua Solis Diametri illuminata.		
6 53 44	29′ 46″	7 24 32	20′ 16″
55 43	29 8	27 31	19 38
57 37	28 30	31 52	19 0
59 36	27 52	37 39	18 22
7 1 11	27 14	52 44	19 0
2 56	26 36	58 1	19 38
4 47	25 58	8 1 5	20 16
6 35	25 20	20 15	25 20
8 25	24 42	24 15	26 36
10 14	24 4	25 55	27 14
12 13	23 26	27 41	27 52
14 20	22 48	30 1	28 30
16 35	22 10	31 55	29 8
18 42	21 32	34 10	29 46
21 49	20 54	35 46	30 24
		fin 38 40	

Omnes istae observationes ope micrometri habitae fuerunt.

1708. Sun's Transits.

	I	II	C
Sept. 10	11h 59′ 59″	2′ 7″	1′ 3″
11	59 32	1 41	0 36½
12	59 8	1 16½	0 12¼
14	58 20½	0 29	59 24¾
15	57 58	0 6	59 2
16	57 34	59 42	58 38

Sept. 16 alt. sup. limb. pro horol.

7 28 55	17° 0′	27 17 nubes	
32 7	17 30	24 11	11 58 29½
35 18	18 0	21 2	58 30
38 30	18 30	4 17 50 (41″)	11 58 30½

Ergo centrum ⊙ fuit in meridiano indicante horologio 11^h 58′ 30″. Ergo, subt. sunt 8″ in alt. ⊙ 44°.

Omnes ipsae observationes ope micrometri habitae fuerunt.

Diameter ⊙ post varias et repetitas observationes per transitum per meridianum et micrometrum non excessit 31′ 48″.

Hora 7^h 31′ 52″ linea ducta per cornua eclipsis distabat a limbo ⊙ illustrato 25′ 30″ et haec linea ad sensum horizonti erat equidistans.

The clock-corrections are deduced as follows:—

	1708, Sept. 12.	1708, Sept. 14.
Clock-times of sun's transit over quadrant	$0^h\ 0^m\ 12^s.2$	$23^h\ 59^m\ 24^s.8$
Clock-times of sun's true meridian . . .	$0^h\ 0^m\ 6^s.6$	$23^h\ 59^m\ 18^s.6$
Mean time	$23^h\ 55^m\ 59^s.9$	$23^h\ 55^m\ 18^s.4$
Clock-correction	$-4^m\ 6^s.7$	$-4^m\ 0^s.2$.

The correction on mean time is therefore $-4^m\ 1^s$ during the eclipse; and as LA HIRE has already applied $+35^s$, the total correction to his times is $-4^m\ 36^s$. The equation of time is $-4^m\ 38^s$, which agrees exactly with LA HIRE's direction to add 2^s more for reduction to apparent time.

The observations of the eclipse of 1710, 28th Feb., are given only in digits and fractions, and these only after the middle.

1711. Transits of ⊙'s Centre.

July 9	12 0 40½	July 16	12 0 52½
12	0 47	17	0 53½
14	50½	19	0 52½

July 15, Vesper, ⊙ Eclipsis.

Horolog.?	Portio Illum. Residua Diam.		
$7^h\ 16^m\ 0^s$	30′ 0″	$7^h\ 37^m\ 9^s$	19′ 8″
21 0	27 25	38 23	18 30
24 45	25 30	39 37	17 52
28 30	23 36	40 51	17 14
31 0	22 18	42 5	16 34
32 14	21 40	43 18	15 57
33 29	21 2	44 32	15 18
34 42	20 24	45 46	14 40
35 55	19 46	47 0	14 2

These cannot be actual observations; the times and measures progress too uniformly.*

"Journal des observations de M. De La Hire au mois de Decembre 1714.

"L'erreur de son Quad. etant sur la fin de l'année de 15″ soustraire l'on aura les midis vrais comme il suit."

1714. Dec. 10	11 58 13	11½	The obs. transits were	11 58 28
18	11 58 1½			58 16½

1715. Maij 3. mane.

Les observations de l'eclipse, telles qu'elles font icy ont este faites avec une horloge qui tardoit à l'egard de celle du cabinet de 21″.

Eclipsis ⊙ cum novo micrometro.

	Digit.	Residuum.	Digit
$8^h\ 12^m\ 16^s$ Initium.	0′ 0″	$9^h\ 26^m\ 0^s$	10′ 30″
17 25	1 0	29 0	10 0
22 50	2 0	35 31	9 0
27 54	3 0	38 42	8 30
32 25	4 0	42 24	8 0
36 20	4 30	44 46	7 30
41 36	5 30	48 10	7 0
44 3	6 0	50 50	6 30
46 45	6 30	54 0	6 0
49 16	7 0	56 51	5 30
52 6	7 30	59 22	5 0
54 56	8 0	10 2 10	4 30
57 30	8 30	8 32	3 30

* I am inclined to think that the practice of "cooking" observations was much more extensively practiced during the last century than is generally supposed. JEAURAT must have been a great sinner in this respect. In the Memoirs of the French Academy for 1779, he has a series of observations of the Pleiades, which are sometimes considered authoritative, but which a very little examination shows to be fabrications of the clumsiest sort, so clumsy in fact that the author might be acquitted of intentional wrong-doing on that very ground. This is followed by a series of meridian observations of Jupiter, including *thirteen consecutive transits*, which give a uniform motion to the geocentric position. Among the observers discussed in the present section I find none but LA HIRE guilty of the objectionable practice, and he only in two or three instances, of which the worst occurs in connection with the solar eclipse of 1715.

	Digit.	Residuum.	
$9^h\ 0^m\ 4^s$	$9'\ 0''$	$10^h\ 12^m\ 14^s$	$3'\ 0''$
3 28	9 30	14 32	2 30
6 32	10 0	17 9	2 0
9 40	10 30	22 28	1 0
15 20	11 3	25 33	0 30
22 0	11 10 max.	28 47 fin.	

Alia observatio ope Imaginis ⊙ a filio. In Tabulam divisam recepta post Telescopium.

Initium.							
8	12	16	0	9	25	26	10½
	17	32	1		29	7	10
	20	12	1½		32	15	9½
	22	42	2		35	16	9
	25	8	2½		38	40	8½
	27	56	3		41	47	8
	30	49	3½		44	30	7½
	33	27	4		47	48	7
	36	17	4½		50	52	6½
	38	35	5		53	40	6
	41*	14	5½		56	43	5½
	44	12	6	10	0	3	5
	49	3	7		2	50	4½
	52	23	7½		6	0	4
	55	30	8		8	52	3½
9	7	6	10		12	1	3
	9	54	10½		17	28	2
	14	27	11		22	30	1
	18	53	11		28	45 finis.	

Diameter ⊙ ope micrometri 31′ 45″.† Tempore observationis horologium musei accelerabat supra verum tempus 16″. Igitur auferendum 16″ observationibus horologii Musaej.

Il faut ajouter 5″ à toutes les observations cy dessus pour les reduire au temps vray.

This is followed by a third table, beginning with Initium 8 12 16, and ending with finis 10 28 47, but without any explanation whatever except "Observationes limitatae ex meis sed cum 5″ pro defectu horologii". The times of the digits are, however, evidently smoothed off, on the curve principle, for they could never have been observed so nicely. I therefore regard them as worthless.

The fourth and fifth tables are as follows :—

Initium.					
8 12 27		52 45	7½	48 21	7
17 39	1	55 41	8	51 21	6½
20 15	1½	9 8 0	10	54 11	6
22 51	2	11 15	10½	56 56	5½
25 27	2½	14 38	11	59 46	5
28 7	3	19 4	11	10 2 48	4½
30 45	3½	25 37	10½	6 0	4
33 24	4	29 1	10	9 10	3½
36 5	4½	32 23	9½	12 10	3
38 46	5	35 43	9	17 42	2
41 29	5½	38 59	8½	22 46	1
44 13	6	42 11	8	28 56 finis.	
49 51	7	45 17	7½		

Il faut retrancher à toutes ces observations 6″.

[After writing this, I find that this may not be the original journal of La Hire, and that the doubtful tables are not found in the original journal. The latter I did not discover till later.]

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* 41 or 42; not legible.

† This being 6″ less than the real semidiameter, the question arises whether the error is in the scale of the micrometer.

Fifth table.

8 12 27	Initium.	52 34	7½	47 59	7
17 43	1	55 41	8	51 3	6½
20 23	1½	9 7 17	10	53 51	6
22 53	2	10 5	10½	56 54	5½
25 19	2½	14 38	11	10 0 14	5
28 7	3	19 4	11	3 1	4½
31 0	3½	25 37	10½	6 11	4
33 38	4	29 18	10	9 3	3½
36 28	4½	32 26	9½	12 12	3
38 46	5	35 27	9	17 39	2
41 25	5½	38 51	8½	22 41	1
44 23	6	41 58	8	28 56	finis.
49 14	7	44 41	7½		

No explanation whatever.

Sun's Transits, etc.

May 1	12 0 43
2	12 0 23½
3	12 0 5¾
4	11 59 48
9	11 58 26.

Sup. limb.

May 9. Alt. ⊙ pro horolog. mane.

7 17 6	26 0	40 33	11 58 36
20 9	26 30	4 37 29	11 58 35½

May 3 Tr. cent. pro. Merid. veri temporis 12 0 14.

Correction 27″ auferenda a tempore seratino. Addenda igitur 10″ tempori transitus centri ⊙ pro quadrantem muralem in altitudinem centro ⊙ 58 26.

The difficulty respecting the duplicate records is cleared up by a comparison with La Hire's observations as printed in the "*Mémoires*" of the Academy for 1715. The first two tables are the records of the original observations themselves, which have been entirely suppressed in publication. The fourth table gives the "cooked" results of the second set of observations "par l'image du soleil", as printed in the Memoirs, and there is little doubt that the third set, which I did not copy, is the same as the first published set "avec le micromètre". The origin of the fifth table does not seem worth investigating.

The results for clock-error are as follows:—

Date.	Clock-time of ⊙'s Transit.			Mean Time.			Clock-correction.	
1715.	*h*	*m*	*s*	*h*	*m*	*s*	*m*	*s*
May 1	0	0	48.9	23	56	51.9	− 3	57.0
2	0	0	29.8		56	44.0	− 3	45.8
3	0	0	12.5		56	36.7	− 3	35.8
4	23	59	55.1		56	30.0	− 3	25.1

The error of the clock with which the transits of the sun were observed may be supposed $-3^m\ 37^s$ during the eclipse. This clock, however, was not that with which the eclipse was observed: respecting the latter, we have only the statement that it was 21 seconds slower. The correction of the clock actually used was therefore

$$-3^m\ 16^s.$$

1715, 25 July. Mane. Occult. ♃ a ☽.

Immersio limbi prioris ♃ in partem lunae lucidam	1 31 35
limbi posterioris ♃	1 32 51
Limbus prioris ♃ et transit immersionis	2 17 21
posterioris	2 18 37

July 22.	⊙ centre transit	11 59 $58\frac{1}{2}$	
23.	. . . . . .	59 $40\frac{3}{4}$	
24.	☾ limb. post.	6 20 16	
	Veri tempore, Qua. mur. .	6 20 34	[*i. e.*, he adds 18^s for clock-correction and 4″ for error of quadrant.]
	per merid. .	6 20 38	
	♃ tr. centri	7 8 $10\frac{1}{2}$	
	true time	29	
	per meridian	39	[So he considers the correction 10″.]
	⊙ tr. centri	11 59 $25\frac{1}{4}$	
	per meridian	11 59 $37\frac{1}{2}$	[Correction 12″, it seems.]
July 25.	⊙ centre tr.	11 59 $7\frac{1}{4}$	
	per meridian	11 59 19	

I find no further data for the correction of the quadrant.

From the transits of the sun we have:—

Date.	⊙'s Dec.	Corr.	Clock-time of Transit over True Meridian.	Mean Time of Transit.	Clock-correction.	Hourly Rate.
	°	*s*	*h m s*	*h m s*	*m s*	*s*
July 22	+ 20.3	+ 13.4	0 0 11.9	0 5 47.9	+ 5 36.0	0.84
23	20.1	13.1	11 59 53.8	0 5 50.1	+ 5 56.3	0.75
24	19.9	12.8	11 59 38.0	0 5 52.2	+ 6 14.2	0.82
25	19.7	12.5	11 59 19.7	0 5 53.6	+ 6 33.9	

Interpolating between the transits of the sun on July 24 and 25, we find, for the times of the four contacts:—

	(1)	(2)	(3)	(4)
Clock-corrections	$+6^m\ 25^s.3$	$+6^m\ 25^s.3$	$+6^m\ 25^s.8$	$+6\ 25^s.8$
Paris mean times	$1^h\ 38^m\ 0^s.3$	$1^h\ 39^m\ 16^s.3$	$2^h\ 23^m\ 46^s.8$	$2^h\ 25^m\ 2^s.8$
Greenwich mean times	$1^h\ 28^m\ 39^s.3$	$1^h\ 29^m\ 55^s.3$	$2^h\ 14^m\ 25^s.8$	$2^h\ 15^m\ 41^s.7$.

1718, Sept. 9.

8 43 34 l'Immersion d'une petite etoile par le corps de la lune.

Sept. 5	⊙ tr.	11 58 $57\frac{1}{2}$	12 1 7	12 0 $2\frac{1}{4}$
8		57 $32\frac{1}{2}$	59 $40\frac{1}{2}$	58 $36\frac{1}{2}$
10		56 $35\frac{1}{2}$	58 $43\frac{1}{2}$	57 $39\frac{1}{2}$

The clock-corrections from the transits of the sun are:—

Date.	⊙'s Dec.	Corr.	Clock-time of Transit over True Meridian.	Mean Time of Transit.	Clock-correction.	Hourly Rate.
1718.	°	*s*	*h m s*	*h m s*	*m s*	*s*
Sept. 5	+ 6.8	− 3.3	12 59 58.9	23 58 30.2	− 1 28.7	0.38
8	5.7	4.2	58 32.3	57 30.8	− 1 1.5	0.36
10	4.9	4.9	57 34.6	56 50.2	− 0 44.4	

We hence obtain:—

Clock-correction for the time of immersion . . .	$-\ 49^{s}.9$
Paris mean time, September 9	$8^{h}\ 42^{m}\ 44^{s}.1$
Greenwich mean time	$8^{h}\ 33^{m}\ 23^{s}.1.$

The star is B. A. C. 8184.

Series III.

Observations by Delisle *at or near the Luxemburg.*

Volume 113, MS. No. 1012. Observations Astronomiques, faites au Luxembourg par De l'Isle. (About 750 toises *north* of the Observatory.)

1713, Novembre 30.	⊙ on gnomon	11 59 57¾		
Dec. 1.	" " "	0 0 24½		
	Occultation of τ Tauri (5th mag.), 2 Dec., matin .	0 9 19 clock;	0 ?8 39¾ t. vr.	
Dec. 3.	⊙ on gnomon	0 1 22¾		
4.	" " "	0 1 54		

1713, June 21. Error of gnomon per equal altitudes less than 1^{s}.
1714, Jan. 26. Morning alt. $8^{h}\ 49^{m}\ 0^{s}$ = evening alt. $3^{h}\ 12^{m}\ 47^{s}$.

Mean of this and 8 others gives transit of ⊙ = ... 0 0 41.2
(The correction for change of dec. being -13^{s}.)
⊙ on gnomon 0 0 40¾

From the observations on January 26, 1714, the correction of the gnomon is about $+0^{s}.4$. This correction may be considered as applicable to the transits of December 1 and 3 previous. We thus have:—

	1713, Dec. 1.	1713, Dec. 3.
Clock-times of ⊙'s transit	$0^{h}\ 0^{m}\ 24^{s}.9$	$0^{h}\ 1^{m}\ 23^{s}.2$
Mean times	$-10^{m}\ 27^{s}.0$	$-\ 9^{m}\ 39^{s}.9$
Clock-corrections	$-10^{m}\ 51^{s}.9$	$-11^{m}\ 3^{s}.1.$

Clock-time of occultation of τ Tauri, Dec. 1	$12^{h}\ 9^{m}\ 19^{s}.$
Clock-correction	$-10^{m}\ 54^{s}.7$
Paris mean time	$11^{h}\ 58^{m}\ 24^{s}.3$
Greenwich mean time	$11^{h}\ 49^{m}\ 3^{s}.3.$

1714, Mar 20. Imm. of ✱ B of 6th mag . . . 9 6 50 clock. 9 8 21 t. vr.
The star passed only 4′ within the moon's southern limb.
1714, Mar 21. Imm. of o Tauri, 6th mag. . . 10 15 54½ clock. 10 18 9¼ t. v.
Cette immersion a été observée à l'observatoire à 10 18 9 t. vray.

Mar 17.	⊙ on meridian per equal altitudes (6 in number) . .	0 0 45¼ }
"	" " gnomon	0 0 44¼ }
18.	" " "	0 0 4½
20.	" " "	11 58 45
"	" " meridian per 10 equal altitudes	11 58 45.4
21.	" Limb on gnomon	11 59 8
	Transit of semidiameter from other days	1 5
	"Le pendule a retardi de 23″ du le 20 au 21 sur le moien mouve. du Soleil."	11 58 3
22.	⊙ on gnomon	11 57 21½

Applying $+0^s.7$ for correction of gnomon, we have the following clock-corrections from transits of the sun:—

Date.	Clock-time of Transit of ☉ over True Meridian.	Mean Time of Transit.	Clock-correction.
1714.	h m s	h m s	m s
Mar. 17	0 0 45.2	0 8 41.2	+ 7 56.0
18	0 0 5.2	0 8 23.4	+ 8 18.2
20	11 58 45.4	0 7 46.8	+ 9 1.4
21	11 58 3.7	0 7 28.4	+ 9 24.7
22	11 57 22.2	0 7 9.8	+ 9 47.6

The clock-rate seems very good for this epoch. Interpolating the clock-corrections to the times of the occultations, we have:—

	1714, Mar. 20, ∗ B.	1714, Mar. 21, o Tauri.
Clock-times of occultation . .	9^h 6^m 50^s.	10^h 15^m $54^s.5$
Clock-corrections	$+9^m$ $10^s.2$	$+9^m$ $34^s.4$
Paris mean times	9^h 16^m $0^s.2$	10^h 25^m $28^s.9$
Greenwich mean times	9^h 6^m $39^s.2$	10^h 16^m $7^s.9$.

I have not certainly identified ∗ B, but it is near B. A. C. 1373.

1714, April 7, Matin. Imm. of ξ Sagittarii (bright limb). . . . 3 20 48 clock. 3 24 22½ t. vr.
(Suddenly to the ½ second), Emersion (dark limb). 4 34 1½ clock. 4 37 38 t. vr.

Il y avoit deja quelques seconds que l'etoile avoit touché le bord eclairé de la lune & elle paraissoit se meler avec l'oudulation qui se faisoit tout autour du bord eclairé.

(Page 75.) He adds that at the Observatory the observed times were, Immersion 3 24 19; Emersion 4 37 25. He is surprised at the differences of 3½ and 13^s, and enters into a long account of his grounds for believing that the error is not on his side, the only weak point being the want of a clock-error between the 5th and 8th. He considers it possible, however, that he may have forgotten to subtract the 10^s which he counted between the moment of emersion and that of noting the clock-time; if so, his time should be 4 37 28.

Apr. 5.	☉ on gnomon,	11 57 32½
8.	" " "	11 55 30
9.	" " "	11 54 50
10.	" " "	11 54 6

Applying $+0^s.5$ for gnomon, we have:—

	1714, April 5.	1714, April 8.
Clock-times of ☉'s transit . .	11^h 57^m $33^s.0$	11^h 55^m $30^s.5$
Mean times	0^h 2^m $48^s.7$	0^h 1^m $55^s.6$
Clock-corrections	$+5^m$ $15^s.7$	$+6^m$ 25^s 1.

Occultation of ξ Sagittarii, April 6:—

	Immersion.	Emersion.
Clock-times of observation .	15^h 20^m 48^s	16^h 34^m $1^s.5$
Clock-corrections	$+5^m$ $53^s.6$	$+5^m$ $54^s.8$
Paris mean times	15^h 26^m $41^s.6$	16^h 39^m $56^s.3$
Greenwich mean times . . .	15^h 17^m $20^s.6 \pm 2^s$	16^h 30 $35^s.3 \pm 2^s$.

These times agree so well with those noted at the Observatory (see *post*) that his opinion of a difference of ten seconds seems to be erroneous.

1714, Sept. 27 (p. 101), Soir Emersion of Tauri (5th mag.), dark limb, 9 18 42 cl. 9 19 8¼ t. vr.
Oct. 3. Matin Em. of *u* (?) Scorpii, very exact, dark limb, 2 58 14 cl. 2 58 9 t. vr.

Sept.	19.	⊙ on gnomon . . .	11 58 7	La pendule a été avancée de 2 minutes.
	20.	. . . .	11 59 46½	
	22.	Second limb . . .	0 0 19	La pend. a été avancée 1 minute.
			— 1 3½	
	24.	Second limb . . .	0 0 38	
			— 1 3½	
	25.	Cent.	11 59 16½	Pend. avanceé 1 minute.
	26.	. . . .	11 59 58½	
	27.	. . . .	11 59 40½ (?)	Le fil n'etoit pas trop bien placé auprès du pied du style.
Oct.	1.	. . . .	11 58 31	La pend. avancée 2 minutes.
	2.	. . . .	0 0 14½	
	3.	. . . .	11 59 59½	
	5.	. . . .	11 59 30¼	

It cannot be inferred from the statements whether the clock was put forward before or after the transits of the sun.

Applying no correction to the gnomon, which seems to have been adjusted with great care, we have the following results for clock-correction:—

Date.	Clock-time of ⊙'s Transit.	Mean Time.	Clock-correction.
1714.	*h m s*	*h m s*	*m s*
Sept. 26	11 59 58.5	11 51 19.9	— 8 38.6
Sept. 27	11 59 40.5	11 51 0.0	— 8 40.5
Oct. 1	11 58 31.0	11 49 42.4	— 8 48.6
Oct. 2	0 0 14 5	11 49 23.8	—10 50.7
Oct. 3	11 59 59.5	11 49 5.4	—10 54.1

We hence deduce:—

	ω^2 Tauri.	a Cancri.
Clock-times of emersion,	1714, Sept. 27, $9^h\ 18^m\ 42^s$.	Oct. 2, $14^h\ 58^m\ 14^s$.
Clock-corrections	$-8^m\ 41^s.3$.	$-10^m\ 52^s.7$.
Paris mean times	$9^h\ 10^m\ 0^s.7$.	$14^h\ 47^m\ 21^s.3$.
Greenwich mean times	$9^h\ 0^m\ 39^s.7$.	$14^h\ 38^m\ 0^s.3$.

The designation of the second star is clearly a mistake.

1715, May 3, Matin. Beginning of Eclipse ⊙ . . 8 12 57 clock = 8 12 35 t. vr.
End . . . . 8 28 0 = 8 28 38

But owing to the intervention of clouds, he is not sure but that the latter moment is some seconds too early.

La pendule a été arreté.

				Centre.
May	1.	⊙ I. limb on gnomon	11 58 45½ + 1	6
	2.	Centre	11 59 35	

June 28. He does not give the clock-times of the occultation of Venus, but only the t. vr. 1 30 19 and 2 37 17, as already printed.

"Je suis sorti de Luxembourg a la fin du mois de Septembre 1715 par ordre de Madame la Duchesse de Berry."

The observations of the eclipse on May 2 do not admit of an accurate reduction, owing to the stopping of the clock. DELISLE's reduction may therefore be accepted. The equation of time being $-3^m\ 22^s$, the times are:—

Beginning of eclipse	$8^h\ 9^m\ 13^s$	Paris mean time.
	$9^h\ 59^m\ 53^s$	Greenwich mean time.
End of eclipse	$8^h\ 25^m\ 16^s$	Paris mean time.

The next observations are made at the *Hotel de Tarranne*, about 1′ north of the Observatory, and about $0^s.7$ west, so that the longitude east of Greenwich may be supposed $9^m\ 20^s.3$.

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Page 90.—Occultation of Aldebaran, 1717, Sept. 25, soir.

"Le bord de la lune était denteté à cause de sa proximité à l'horizon & Aldeb. toucha cette denteture à 9 12 15 de la pendule, au quel tems je ne le pus plus distinguer. Le tems vrai est à 9 11 38."

Emersion, dans un instant 10 4 34½, Pend. = 10 3 57.

Sept. 25. Alt. ⊙ Lower L.

			Midy vray.	
7 31 27	16° 35′	4 1 3	11 46 36	Moyen 11 46 37.2.
33 40	16 55	3 58 54	38	
35 51	17 15	56 41	37	
38 2	17 35	54 31	37½	

La pendule a été avancée de 14′.

Sept. 26. Alt. ⊙ 12 obs. The first and last are:—

7 47 23	16 35	4 13 8	0 0 36½	Mean of 12, 0 0 38½; gnomon 0 0 23.
8 11 53	20 15	3 48 44	0 0 39½	

The clock-corrections are derived as follows:—

	1717, Sept. 25.	1717, Sept. 26.
Clock-times of ⊙'s transit	$0^h\ 0^m\ 37^s.2$	$0^h\ 0^m\ 38^s.3$
Mean times	$23^h\ 51^m\ 34^s.6$	$23^h\ 51^m\ 14^s.6$
	$-9^m\ 2^s.6$	$-9^m\ 23^s.7$.

Occultation of α Tauri:—

	Immersion.	Emersion.
Clock-times	$9^h\ 12^m\ 15^s$	$10^h\ 4^m\ 34^s.5$
Clock-corrections	$-9^m\ 10^s.7$	$-9^m\ 11^s.5$
Paris mean times, September 25 . . .	$9^h\ 3^m\ 4^s.3$	$9^h\ 55^m\ 23^s.0$
Greenwich mean times	$8^h\ 53^m\ 44^s.0$	$9^h\ 46^m\ 2^s.7$.

But the immersion may be observed a little early.

1718, Jan. 16. $1^h\ 27'\ 14''$. Immersion of λ Geminorum ($15^d.6$, I think).

Jan. 16.	Tr. of sun per. corresp. altitudes (uncorr.)	0 4 13.8
	Mean interval, $6^h\ 12^m$ corr.	11.
	Gnomon $0^h\ 4'\ 1''.0 = \Phi$	0 4 2.8

Jan. 11.	Φ = 0 7 1	et 8′ a été retranché.
Jan. 12.	11 59 57	
16.	0 4 1.0	la pendule a été retardé de 4′.
18.	0 2 29.5	

Adding 1^s for gnomon, taking the time of transit for January 16 from the corresponding altitudes (true correction — $11^s.6$), and reducing the artificial changes in the clock to its state on January 15, we have:—

Date.	⊙'s Transit per Clock.	Mean Time of Transit.	Clock-correction.	Hourly Rate.
1718.	h m s	h m s.	m s	s
Jan. 11	11 59 2.0	0 8 33.3	+ 9 31.3	
				− 1.36
12	11 59 58.0	8 56.6	8 58.6	
				− 1.64
16	0 4 2.2	10 23.7	6 21.5	
				− 2.27
18	0 6 30.5	11 3.1	+ 4 32.6	

Interpolating the clock-correction to the time of observation, we have:—

Clock-time of immersion of λ Geminorum, 1718, Jan. 15 . . .	$13^h\ 27^m\ 14^s$
Clock-correction	$+6^m\ 41^s$
Paris mean time	$13^h\ 33^m\ 55^s$
Greenwich mean time	$13^h\ 24^m\ 34^s.7 \pm 2^s$.

Page 127.—1718, Feb. 9. Soir. Imm. Aldebaran* 6 19 44 = 6 16 48 t. vr., or 6 16 53, which he thinks is more exact, because derived from transits of stars as well as ⊙. Afterward he finds that 6 16 48 is after all the most probable time from the mean of all methods. The probable error does not seem to be so much as 2^s

Feb. 6. ⊙ on gnomon . . . . 0 8 41 Pend. ret. 9 min.

Clock has gained 5′ since Feb. 1, about 1′ per day.

Feb. 10. ⊙ on gnomon 0 3 39

The correction to gnomon is $+0^s.7$.

Accepting DELISLE's reduction, the equation of time being $+14^m\ 47^s.4$, we have:—

Paris mean time of occultation of Aldebaran, 1718, Feb. 9 . .	$6^h\ 31^m\ 35^s.4$
Greenwich mean time	$6^h\ 22^m\ 15^s.1 \pm 2^s$.

Page 133.—*o* Leonis, Feb. 14, soir, l'etoile a paru toucher dans son immersion la partie eclairée. J'ai cessé de l'apercevoir à 6 52 39 de la pendule.

Feb. 14. ⊙ on gnomon, 0 7 43.
15. 0 8 43.

It seems doubtful whether the immersion of *o* Leonis is worth using. The real occultation was probably not seen. There is room for suspecting a change in the correction to the gnomon.

1718, Sept. 9.

$8^h\ 44'\ 49''$ Une etoile se cache sous le bord de la lune.
46

8 45 35

			Cent.		
Aug. 19. ⊙ tr.	$0^h\ 0'\ 45''$	$2'\ 56''$	$1'\ 50''\frac{1}{2}$	Mean int. . . .	$6^h\ 23^m$
Sept. 5.	11 58 $17\frac{1}{2}$	0 $26\frac{1}{2}$	59 22	Uncorr. mean . .	0 3 58.3
7.	58 $12\frac{1}{2}$	0 21	59 $16\frac{3}{4}$	Corr.	+ 16
8.	58 9	0 17	59 13	Aug. 19. Mean int.	11 28
10.	58 11	0 19	59 15	Mean of 9 corr. alts.	0 1 32.1
Nov. 8.	3 8†	5 25	4 $16\frac{1}{2}$	Correction . . .	20

Nov. 8.—12 corr. alts. ⊙.

* This same occultation DELISLE says was observed at Toulon, "dans le Semenaire Royal de la Marine," by Le P. LAVAL. Imm. 6 40 27, Em. 7 47 40, Dur. 1 7 13; the clock being corrected by different corresponding heights of the sun on the 9th and 10th.

† Somewhat doubtful, from being obliged to use a watch in counting the seconds.

The results for clock-error are derived thus:—

Date.	Clock-time of ⊙'s Transit.			Mean Time.		Clock-correction.		Hourly Rate.
1718.	h	m	s	m	s	m	s	s
Sept. 5	11	59	22.5	58	30.3	− 0	52.2	+ 0.72
7			17.3	57	50.7	1	26.6	+ 0.67
8			13.5	57	30.8	1	42.7	+ 0.89
10			15.5	56	50.2	− 2	25.3	

We have:—

Aug. 19.	Correction of equal altitudes	$+21^s.1$
	True transit	$0^h\ 1^m\ 53^s.2$
	Gnomon	$1^m\ 50^s.5$
	Correction	$+\ 2^s.7.$
Nov. 8.	Correction of equal altitudes	$+15^s.8$
	True transit	$4^m\ 14^s.1$
	Gnomon	$4^m\ 16^s.5$
	Correction	$-\ 2^s.4.$

I have used $+0^s.5$.

We then have, for the time of occultation:—

Clock-time, 1718, September 9	$8^h\ 44^m\ 49^s.$
Clock-correction	$-2^m\ 11^s.8$
Paris mean time	$8^h\ 42^m\ 37^s.2$
Greenwich mean time	$8^h\ 33^m\ 16^s.9 \pm 2^s.$

Page 245.—1719, Apr. 22, soir. Imm. Aldeb. dark limb, 7 44 44 clock = 7 44 32 t. vr.
Em. " bright " 8 34 24 = 8 34 14

Dans cette observation l'etoile n'etoit point encore detachée du bord eclairé de la lune.

Apr. 22.	True noon per 13 pairs equal altitudes	0 0 31.7
	⊙ on gnomon	0 0 32.5
23.	" " "	11 59 31.5

The results of the observations are:—

	Apr. 22.	Apr. 23.
Clock-times of sun's transit	$0^h\ 0^m\ 31^s.7$	$11^h\ 59^m\ 30^s.7$
Mean times	$25^h\ 58^m\ 25^s.8$	$23^h\ 58^m\ 13^s.4$
Clock-corrections	$-2^m\ 5^s.9$	$-1^m\ 17^s.3.$

Occultation of Aldebaran.

	Immersion.	Emersion.
Clock-times of phase, 1719, April 22 .	$7^h\ 44^m\ 44^s$	$8^h\ 34^m\ 24^s.$
Clock-corrections	$-1^m\ 50^s.2$	$-1^m\ 48^s.6$
Paris mean times	$7^h\ 42^m\ 53^s.8$	$8^h\ 32^m\ 35^s.4$
Greenwich mean times	$7^h\ 33^m\ 33^s.5$	$8^h\ 23^m\ 15^s.1.$

Page 249.—1719, Aug. 21. Imm. γ Libræ, very exact, 7 41 31 cl. = 7 40 12 t. vr.

Equal altitudes of ☉'s lower limb (?).

	Aug. 21.		Aug. 22.		
Alt.	A. M.	P. M.	A. M.	Mean Aug. 22.0 . .	0 18 40
				Corr.	+ 19
11° 45′	6 31 42½	6 5 28½	6 16 43		
13 45	44 0½	5 53 13	28 58½		0 18 59
14 15	47 3	50 3	32 3	Subtr.	19 0
20 25	7 24 47	12 32			
20 45	26 47	10 32	7 11 47½	Aug. 22.0	11 59 59
21 5	28 54	8 27	13 52	Aug. 22.5. Mean of last 2,	0 1 40
				Correct.	23
					0 2 3

Clock put back 19 minutes between Aug. 21, p. m., and Aug. 22, a. m.
Owing to clouds and fog, DELISLE rejects the three top lines altogether.

DELISLE's correction for midnight seems all wrong. The corrections for noon and midnight are $+18^s.6$ and $-27^s.4$ respectively, whence we obtain:—

	1719, Aug. 21.0.	1719, Aug. 21.5.
Clock-times of sun's transit, corrected for change of 19^m	$23^h\ 59^m\ 58^s.4$	$12^h\ 1^m\ 12^s.2$
Mean times	$0^h\ 2^m\ 51^s.2$	$12^h\ 2^m\ 44^s.1$
Clock-corrections	$+2^m\ 52^s.8$	$+1^m\ 31^s.9$

Clock-time of immersion of γ Libræ, 1719, August 21 .	$7^h\ 41^m\ 31^s.$
Clock-correction	$+2^m\ 1^s.1$
Paris mean time	$7^h\ 43^m\ 32^s.1$
Greenwich mean time	$7^h\ 34^m\ 11^s.8.$

The dates Aug. 22.0 and Aug. 22.5 in my manuscript, and as printed above without change, are, without serious doubt, one day in error. The computation is, however, that of DELISLE, and it is evident that he has deduced his "Temps vray" from the erroneous deduction of the clock-time of midnight.

Page 259.—1719, Oct. 30 (?) Immersion of Aldebaran (inst.) 8 56 34 clock = 9 2 54 t. vr.
Emersion, dark limb. . . . 9 53 3½ = 9 59 29½
Duration 56 29½

Oct. 29.	Equal alt. ☉.	Oct. 30.	12 altitudes very accordant.	
8 27 27	3 13 45	7^h 47′ 12″	7° 25′	4^h 1′ 14″½
30 0	11 9	. . .	. .	. . .
32 38	8 32	. . .	. .	. . .
35 21½	5 49	. . .	. .	. . .
38 3½	3 5	8 13 56	11 5	3 34 29
40 46	0 24			

Mean noon Oct. 29	11 50 35	Mean of 12	11 54 12.9
	18½	Correction	+ 19.5
Corrected	11 50 53½		11 54 32.5
Clock advanced	6 0		
	11 56 53½		

The corrections for motion of sun in declination I find to be $+18^s.6$ and $+19^s.0$. The reduction of the observations therefore stands:—

	1719, Oct. 29.	1719, Oct. 30.
Clock-times of transit of ⊙	$11^h\ 56^m\ 53^s.6$	$11^h\ 54^m\ 31^s.9$
Mean times	$11^h\ 43^m\ 58^s.0$	$11^h\ 43^m\ 54^s.8$
Clock-corrections	$-\ 12^m\ 55^s.6$	$-\ 10^m\ 37^s.1$.

The clock-correction must now be carried forward eight hours with the rate derived from the observations of the two days.

Occultation of Aldebaran.

	Immersion.	Emersion.
Clock-times of phase, 1719, Oct. 30 .	$8^h\ 56^m\ 34^s$.	$9^h\ 53^m\ 3^s.5$
Clock-corrections	$-9^m\ 44^s.9$	$-9^m\ 39^s.4$
Paris mean times	$8^h\ 46^m\ 49^s.1$	$9^h\ 43^m\ 24^s.1$
Greenwich mean times	$8^h\ 37^m\ 28^s.8\ \pm 3^s$	$9^h\ 34^m\ 3^s.8\ \pm 3^s$.

These times are 1^s greater than those obtained by correcting DELISLE's result for the equation of time, $-16^m\ 6^s$. The difference arises from the change of $0^s.5$ in the correction for noon on October 30.

Total eclipse of ⊙, 1724, May 22.8 (?). 2d part of page 95. At the Royal Observatory, whither he had transported his instruments.

J'ay commencé à l'apercevoir à $5^h\ 53'\ 24''$ de ma pendule, mais le vray commencement a peu arriver un peu plustot, parceque je ne regardois pas dans ce tems la precisement à l'endroit ou la lune est entree, et que je ne m'en suis apercu que lorsqu'elle occupoit une petite portion de quelques degres du bord du soleil. Le tems vray est à 5 55 18 d'ou je crois pouvoir mettre le commencement a 5 55 0. La Totalité m'a paru se faire à 6^h 46 55 pend = 6 48 54 t. vr. Le recouvrement de lumiere m'a aussi paru se faire 6 49 13 = 6 51 12, ainsi l'obscurite a duré $2'\ 18''$.

May 21. CASSINI's clock at app. noon 11 57 0 from 16 equal alts. He afterward put the clock forward $3'$. Allowing for this, the sun passed the mural quadrant as follows:—

May 21	11 59 56
22	11 59 51
24	11 59 48

Comparison of clocks, May 22, evening.

DELISLE	3 18 27	19 27	5 3 16½	4 16½	7 11 4	12 3½
CASSINI	20 0	21 0	5 0	6 0	13 0	14 0
Diff.	1 33	1 33	1 43½	1 43½	1 56	1 56½

I have not yet reduced and discussed these observations.

1725, Feb. 19.5. Imm. of Tauri, exact dark limb. $0^h\ 14'\ 24'' = 0^h\ 11'\ 18''$ t. vr.

Corrections of Gnomon.	s	Transits of ⊙ over Gnomon.			
Jan. 8	0.0	Feb. 17	0	2	4¼
Sept. 13	+ 2.7	19	0	2	52.7
20	− 0.7	20	0	3	19.1

Assuming the gnomon to be correct, the reduction stands:—

	Feb. 19.	Feb. 20.
Clock-times of transit	$0^h\ 2^m\ 52^s.7$	$0^h\ 3^m\ 19^s.1$
Mean times	$0^h\ 14^m\ 18^s.7$	$0^h\ 14^m\ 12^s.0$
Clock-corrections	$+11^m\ 26^s.0$	$+10^m\ 52^s.9$.

Immersion of A^1 Tauri, clock-time, 1725, Feb. 19 . .	$12^h\ 14^m\ 24^s$.
Clock-correction	$+11^m\ 9^s.2$
Paris mean time	$12^h\ 25^m\ 33^s.2$
Greenwich mean time	$12^h\ 16^m\ 12^s.9$.

Series IV.

This is perhaps to some extent a continuation of Series I., by the Cassinis and Maraldis. I have not attempted to identify the individual observers. The system of observation was the same as before, the transits of the sun being regularly observed with the mural quadrant, and the true times of transit occasionally determined by corresponding altitudes, and the correction of the quadrant thence determined. I have re-reduced all these observations that I could find. There is, however, a hiatus extending from 1728 to 1756, within which an entirely independent derivation of clock-errors does not seem possible. Thus, curious though it may seem, the place of the moon is much better determined during the first quarter of the last century than during the second.

The computation of the correction of the quadrant from the sets of equal altitudes is shown in the following table, which does not seem to need any special explanation.

Investigation of Corrections to the Paris Quadrant, 1706–1758.

Date.	Clock-time of Mean of Corresponding Altitudes.	Mean Interval.	Hourly Motion of Sun's Dec.	Corr. for Motion.	Clock-time of Transit over Meridian.	Clock-time of Transit over Quadrant.	Corr. of Quadrant.	Sun's Declination.
	h m s	h m	"	s	m s	m s	s	° ′
1706, May 14	23 59 20.2	4 14	+ 36.4	− 8.1	59 12.1	59 42.0	− 29.9	+18 35
Aug. 1	23 55 15.4	6 13	− 37.6	+ 9.9	55 25.3	55 59.0	− 33.7	+18 6
Sept. 19	23 58 46.0	4 54	− 58.2	+ 17.9	59 3.9	59 39.0	− 35.1	+ 1 34
Dec. 5	23 58 52.2	4 31	− 19.2	+ 7.7	58 59.9	. .	. .	−22 22
1707, April 4	23 50 26.2	4 25	+ 57.3	− 16.5	50 9.7	50 47.5	− 37.8	+ 5 32
June 19	23 55 32.2	5 35	+ 2.8	− 0.6	55 31.6	56 2.0	− 30.4	+23 26
Sept. 6	23 58 8.7	4 42	− 55.8	+ 15.8	58 24.5	59 0.8	− 36.3	+ 6 37
1708, Feb. 24	23 56 25.5	4 13	+ 44.4	− 16.6	56 8.9	56 44.0	− 35.1	−16 25
July 9	23 58 31.9	4 33	− 18.2	+ 4.3	58 36.2	59 7.2	− 31.0	+22 21
Sept. 12	23 58 26.0	4 47	− 57.4	+ 16.9	58 42.9	59 18.8	− 35.9	+ 4 4
1709, Dec. 24	23 57 20.2	4 11	+ 2.9	− 1.2	57 19.0	57 53.	− 34.0	−23 26
1710, Feb. 9	23 51 59.8	5 6	+ 48.1	− 17.8	51 42.0	52 17.0	− 35.0	−14 43
July 22	23 56 56.7	5 3	− 29.7	+ 7.0	57 3.7	57 35.0	− 31.3	+20 20
Sept. 13	23 53 51.3	4 41	− 57.5	+ 16.9	54 8.2	54 47.5	− 39.3	+ 3 52
Dec. 4	23 52 17.	4 10	− 20.3	+ 8.1	52 25.1	53 1.0	− 35.9	−22 14
1711, Sept. 15	23 50 39.5	4 16	− 57.8	+ 17.0	50 56.5	51 33.2	− 36.7	+ 3 13
1714, Mar. 16	23 57 57.2	4 44	+ 59.2	− 18.7	57 38.5	. .	. .	− 1 48
Mar. 20	23 57 9.0	6 1	+ 59.3	− 19.2	56 49.8	57 28.5	− 38.7	− 0 13
1715, May 26	0 1 32.1	4 42	+ 26.4	− 8.0	1 24.1	2 1.	− 36.9	+21 3
July 26	0 0 13.3	4 34	− 32.7	+ 7.5	0 20.8	1 0.0	− 39.2	+19 33
Sept. 16	23 56 44.5	4 27	− 57.9	+ 17.3	57 1.8	57 43.	− 41.2	+ 2 50
Nov. 3	23 59 57.9	4 5	− 47.2	+ 17.4	0 15.3	0 50.5	− 35.2	−14 56

Investigation of Corrections to the Paris Quadrant, 1706–1758—Continued.

Date.	Clock-time of Mean of Corresponding Altitudes.	Mean Interval.	Hourly Motion of Sun's Dec.	Corr. for Motion.	Clock-time of Transit over Meridian.	Clock-time of Transit over Quadrant.	Corr. of Quadrant.	Sun's Declination.
	h m s	h m	″	s	m s	m s	s	° ′
1717, Sept. 20	23 55 48.7	4 20	− 58.4	+ 17.6	56 6.3	56 45.0	− 38.7	+ 1 5
Dec. 19	0 0 38.0	3 58	− 3.0	+ 1.2	0 39.2	1 12.5	− 33.3	−23 26
1718, Sept. 27	23 59 8.7	4 15	− 58.5	+ 18.2	59 26.9	0 10.5	− 43.6	− 1 34
1720, May 21	0 0 16.	4 42	+ 30.0	− 6.8	0 9.2	0 45.0	− 35.8	+20 17
May 28	23 59 4.	4 33	+ 23.8	− 5.3	58 58.7	59 35.5	− 36.8	+21 33
1727, Mar. 21	23 59 22.2	6 0	+ 59.3	− 19.2	59 3.0	59 44.2	− 41.2	+ 0 8
1728, Feb. 13	23 53 19.	4 12	+ 50.2	− 18.2	53 0.8	53 45.0	− 44.2	−13 31
Aug. 30	23 48 19.5	2 7	− 54.0	+ 13.8	48 33.3	49 17.2	− 43.9	+ 8 52
1755, July 18	0 8 7.7	5 54	. .	+ 6.5	8 14.2	8 10.1	+ 4.1	. .
1756, Dec. 13	0 9 21.2	5 38	− 9.2	+ 3.7	9 24.9	9 31.2	− 6.3	−23 13
Dec. 17	. . . . .	. .	− 4.6	. .	. .	. .	. .	−23 24
1758, Jan. 24	0 22 6.2	5 2	+ 36.4	− 14.2	21 52.0	22 2.0	− 10.0	−19 9

It will be seen that the series of occultations which we use begins nine months before the first determination of the error of the quadrant, and that, during the interval, the observers used a correction for deviation much smaller than that found from and after 1706, May 14. There is no way of determining whether there really was a change, or of deciding how the value actually used was obtained. I am strongly inclined to suspect that the value actually used was the result of some old determination, which was found to be erroneous when equal altitudes began to be regularly observed, and that the new value should be used from the beginning of the series. What has been done is to make the reductions on each hypothesis in order that the results might be compared.

The deviations of the quadrant resulting from the observations vary with the time and the declination in a manner which does not seem reducible to any exact law. I have therefore, in determining clock-corrections from the several transits, tried to execute a sort of double interpolation of the quadrant-error from observations each side of the date in time and each side of the declination in altitude. The corrections thus deduced are shown in the following table of individual clock-corrections.

Instead of discussing each clock-correction separately, as in the former series of observations, I have in this series, owing to the uniformity of the processes, collected all the individual results into a single table. Generally at least one determination is made on each side of the time of observing the occultation, and the correction for the time of observation is obtained by a simple interpolation. The table is as follows, and scarcely seems to need explanation. It may be remarked that the column "Mean Time" gives the mean tabular time of transit of the sun over the true meridian, and is simply the equation of time, subtracted from $24^h\ 0^m\ 0^s$ when negative.

The clock of which the corrections are here given was the "pendule supérieure"; most of the occultations were actually observed with another clock, designated as "pendule inférieure", which was compared with the other soon after the occultation.

Computation of Clock-corrections from Transits of the Sun observed at the Paris Observatory.

Date.	Clock-time of Transit over Quadrant.	Correc-tion.	Transit over True Merid.	Mean Time.	Apparent Clock-cor-rection.
	h m s	*s*	*m s*	*m s*	*m s*
1705, Aug. 3	23 58 49.5	− 13 (?)	58 36.5	5 32	+ 6 56
☽ 4	2 0 5.5	− 13	59 52	. .	. .
5	58 8.2	. .	57 55	5 27	+ 7 32
Sept. 2	23 56 33	− 21 (?)	56 12	59 24	+ 3 12
4	55 23	. .	55 2	58 46	+ 3 44
1706, Jan. 21	23 59 45	− 17 (?)	59 28	11 57	+ 12 29
24	59 18	. .	59 1	12 43	13 42
27	58 38	. .	58 21	13 23	15 2
28	58 28	. .	58 11	13 34	+ 15 23
Apr. 21	23 57 6	− 16 (?)	56 50	58 36	+ 1 46
22	56 37	. .	56 21	58 23	+ 2 2
May 24	23 56 40	− 31	56 9	56 13	+ 0 4
26	56 2	. .	55 31	56 24	+ 0 53
Nov. 16	23 59 52	− 35	59 17	45 7	− 14 10
19	59 26	. .	58 51	45 45	− 13 6
1707, Apr. 4	. . .	. .	50 9.7	3 12.4	+ 13 2.7
5	23 50 1.5	− 36.5	49 25.0	2 54	+ 13 29
Sept. 3	23 55 7	− 36	54 31	59 15	+ 4 44
5	53 44	. .	53 8	58 36	+ 5 28
1708, Feb. 23	23 57 26.5	− 35.0	56 51.5	13 57.2	+ 17 5.7
24	. . .	. .	56 8.9	13 48.4	+ 17 39.5
Sept. 5	23 56 26.5	− 37.0	55 49.5	58 21.5	+ 2 32
7	54 31.5	. .	53 54.5	57 41.8	+ 3 47
1709, Apr. 20	23 54 27	− 36	53 51	58 46	+ 4 55
21	53 50	. .	53 14	58 32	+ 5 18
Sept. 13	23 52 17.5	− 35	51 42	55 44.1	+ 4 2
14	51 23.0	. .	50 48	55 23.4	4 35
15	50 26.0	. .	49 51	55 2.5	5 11
16	49 31.5	. .	48 56.5	54 41.7	5 45
☽ 16	10 25 5	. .	24 30	30 33	+ 6 3
20	23 59 32	. .	58 57	53 18	− 5 39
23	56 50	. .	56 15	52 17	− 3 58
1710, Dec. 4	. . .	. .	52 25	50 38.5	− 1 46.5
5	23 52 59	− 36	52 23	51 3.4	− 1 19.6
1711, Sept. 29	23 55 21	− 37	54 44	50 26	− 4 18
☽ 30.6	14 54 23	. .	53 46	50 14	3 32
Oct. 2	53 0.5	. .	52 23	49 29	− 2 54

Computation of Clock-corrections, etc.—Continued.

Date.	Clock-time of Transit over Quadrant.	Correction.	Transit over True Merid.	Mean Time.	Apparent Clock-correction.
	h m s	*s*	*m s*	*m s*	*m s*
1712, May 15	0 2 4	− 33	1 31	55 52	− 5 39
17	2 37	. . .	2 4	55 54	− 6 10
1714, Mar. 21	23 57 16	− 39	56 37	7 28	+ 10 51
22	57 5	. .	56 26	7 10	+ 10 44
Apr. 6	0 0 38	− 39	59 59	2 31	+ 2 32
8	0 11	. .	59 32	1 56	+ 2 24
1715, July 21	0 0 45	− 38	0 7	5 44	+ 5 37
22	0 48	. .	0 10	5 48	+ 5 38
Aug. 9	0 0 16	− 40	59 36	5 4	+ 5 28
10	0 7	. .	59 27	4 56	5 29
16	23 58 57	. .	58 17	3 56	+ 5 39
Oct. 7	23 58 18.5	− 39.5	57 39	47 59	− 9 40
10	58 34.5	. .	57 55	47 10	− 10 45
Dec. 23	0 1 27	− 34	0 53	59 30	− 1 23
30	4 37	. .	4 3	2 58	− 1 5
1716, Jan. 7	0 7 59	− 34	7 25	6 41	− 0 44
1717, Sept. 25	23 58 45.5	− 39.0	58 6.5	51 34.6	− 6 32
26	58 21.2	. .	57 42.2	51 14.6	− 6 28
1718, Sept. 8	0 1 24	− 41	0 43	57 30.8	− 3 12
10	0 34	. .	59 53	56 50.2	− 3 3
1719, Apr. 22	23 58 49.5	− 41.5	58 8	58 25.8	+ 0 18
23	58 27.5	. .	57 46	58 13.1	+ 0 27
Oct. 29	0 0 50	− 40:	0 10	43 58	− 16 12
30	0 33	. .	59 53	43 55	− 15 58
Nov. 26	23 58 32	− 37:	57 55	47 37	− 10 18
27	58 38	. .	58 1	47 57	− 10 4
1720, Apr. 16	23 59 52	− 40	59 12	59 38	+ 0 26
20	58 7	. .	57 27	58 42	1 15
23	56 51	. .	56 11	58 4	+ 1 53
1727, Sept. 6	23 48 44	− 42	48 2	58 15	+ 10 13
8	47 13	. .	46 31	57 35	+ 11 4
1738, Jan. 2	0 4 52	+ 2	4 54	4 40	− 0 14
3	5 46.5	. .	5 48.5	5 7.8	− 0 41
Dec. 23	0 16 18.5	. .	16 20.5	59 39.2	− 16 41
24	16 54	. .	16 54	0 9.3	− 16 45
1739, Feb. 13	. . .	. .	4 57.3	14 43.6	+ 9 46.3
16	0 4 58.7	+ 1.5	5 0.2	14 34.9	+ 9 34.7

More observations, from the anonymous registers, accidentally omitted before:—

Occultation of Jupiter, July 27, 1704.

1^h	$22'$	$34''$	on juge qu'il touchoit par la lunette de 8.
1	22	40	il commença à toucher le bord de l'☽ par la lunette de 18 pieds.
1	24	3	je crois l'avoir perdu de vue.
2	6	26	♃ est sort à moitié.
2	7	12	♃ tout sort.

Transits of ⊙, etc.

		I.	II.	C.	Midy.
July 25	⊙ tr.	11 58 $55\frac{1}{2}$	$1'$ $11''$	12 0 $3\frac{1}{4}$	11 59 52
26		58 52	1 8	12 0 0	59 48
27		58 48	1 2	11 59 55	59 43
28		58 $40\frac{1}{2}$	0 55	59 $47\frac{3}{4}$	. .
29		58 38	0 52	59 45	59 33

He applies a correction of $-12''$ for instrument, but I cannot find on what this correction depends. I find no data for such a correction till December 30, a. m., when we find:—

8 2 27, haut du bord sup. du soleil par M. d. C. $1°$ $7'$ $0''$.
8 6 39, le bord inf. à la mesme hauteur.

Thermometer 25. Bar. $277\frac{1}{2}$.

By rough examination of the temperature at different seasons, the thermometer seems to be that of Fahrenheit. The observed transits of ⊙ are:—

	Cent.	Midy.	
Dec. 25	0 4 7.3	0 3 50.3	So it seems he now applies -17^s for error of instrument.
30	0 5 4.5	0 4 47.5	

If this observation is worth reducing, it is rather to be used for determining the position of Jupiter than that of the moon. The observed altitude of the sun gives a clock-correction of $-1^m\ 41^s$, which is entirely incompatible with that derived from the transits. The only course seems to be to accept the times of apparent noon given by the observers, and correct the clocks accordingly. The apparent times, deduced by applying a clock-correction of $+17^s$, are given in the Memoirs of the Academy for 1704, page 233.

1705, Aug. 5. (Aug. 4.6, astron. time.)

	3^h	$16'$	$40''$	Immersion de l'étoile dans la lune par la lunette de 17 pieds. Je n'ay pas pu voir avec la lunette de 11 pieds.
Add		1	52	
	3	18	32	
	9	5	0	pend. sup. } 6^h after the occultation.
	9	5	8	pend. inf.
		0	8	

Aug. 2	⊙ tr.	11 58 $0''\frac{1}{2}$	$0'$ $15''$	. . . . .	11 59 8	
					13	
					11 58 55	midy.
3	⊙ tr.	11 57 43	59 56	. . . . .	11 58 $49\frac{1}{2}$	
					13	
					11 58 $36\frac{1}{2}$	midy.
4	. . . .				11 58 16	midy (couvert).

	☾ 11 58 50	☽ 1 21		
5	11 57 1½	59 15	. . . . . .	11 58 8
				13
				11 57 55
6	11 56 41	58 54	. . . . . .	11 57 47
				16
				11 57 31

No altitudes; no telling how quadrant was corrected.

The interval of six hours between the observation and the comparison of clocks renders the time more uncertain than usual, the difference -8^s being assumed constant for this time. The transit of the moon might be utilized for the clock-correction, but has not been. The results for local mean time of occultation will be:—

Using CASSINI's correction of quadrant, Aug. 4, $15^h\ 23^m\ 58^s$
Using -35^s . . . . $15^h\ 24^m\ 20^s$

1705, Sept. 2.

11 46 15 horl. inf. l'étoile τ de la 5^e grandeur dans la jambe oriental du Verseau entre dans la partie obscure de la lune.

0 47 37 l'étoile sort.

0 51 0 l'horl. sup.
0 51 39 l'horl. inf.

Sept. 1	⊙ tr.	11 56 0	58 12	11 57 6	
				20	
				11 56 46	midy.
2	⊙ tr.	11 55 28	57 38	11 56 33	
				21	
				11 56 12	midy.

2 0 pendule sup.
2 38 pendule inf.
0 38

Sept. 4 ⊙ tr. 11 54 18 56 29.

The hour of the last clock-comparison cannot be determined.

1706, Jan. 23, p. m.

11 0 14 l'étoile entre dans la partie obscure de la lune par la lunette de 17 et par cette de 11 p.
22 36 l'étoile entre par la lunette de 11 p.
23 19 par cette de 17.
11 32 29 l'étoile petite qui est entrée la derrière sort de la lune 17 p.
32 34 par la lunette de 12 p.
11 38 8 pendule inf.
38 0 pendule sup.

Les observations précédentes de la ☽ ont esté faites à la pendule inf.

Jan. 27½, 1706.

12 21 3 l'étoile λ, entre dans la lune du coté de la partie obscure.
12 25 22 pend. inf.
12 21 0 pend. supr.

			I.	II.	
1706, Jan. 21	☉ tr.		11 58 36	0 54	11 59 45
					17
					11 59 28 midy.
24			58 8½	0 28	
26	☾ tr.		10 22 45	25 4	
27	☉		11 57 28	59 49	
	☾		11 17 8	19 27	
28			11 57 19	59 38	11 58 29
					17
					11 58 12 midy.

On January 23, the first immersion is of $\varkappa^1$ Tauri; the next two appear to be two observations of the immersion of $\varkappa^2$ Tauri. All the observations are, however, discordant in a way which gives rise to the suspicion that an error of 3^m was made in the comparison of clocks.

1706, April 21. Occultation of η Leonis.

8 59 15 Immersion de l'étoile derrière la lune supr. pend.
9 1 45 Immersion de l'étoile η dans le col du Lion avec une lunette de 3 pieds . . . pend. inf.
9 1 47 avec une lunette de 2 pieds.
9 2 0 pendule supr.
9 4 28 pendule infr.
9 55 20 Emersion de l'étoile η de la lune par la lunette de 16 pieds exacte, pendule inf.

L'étoile en entrant dans la lune m'a paru s'allonger estant vue dans l'axe de la lunette de 16. pieds.

Avril	19	☉ tr.	11 57 12 (sic).	59 12 (sic).	
	20		56 31	58 41	
	21		56 1	58 12	
	22		55 32	57 43	
	23		55 3	57 14	
May	11		11 57 38	59 52	2′ ajouté.
	12		59 14	1 30	
	14		58 35	0 49	
	15		—	0 31	

Altitudes of ☉, May 14.

9^h 47′ 45″	2^h 12′ 11″	50° 0′	0 4 0	pend. sup.
50 16	9 36	50 20	0 4 37	pend. inf.
52 50	7 1	50 40		
55 29	4 30	51 0		
58 8	1 46	51 20		

	9 47 45	
	14 12 11	
	4 24 26	
	2 12 13	
	11 59 58	
	8	
	11 59 50	midy à la pendule inf.
	37	
	11 59 13	midy à la pendule supr.
	11 59 42	
	0 29	déclinaison de l'instr.
May 14	11 59 42	
	15	
	11 59 27	midy.

This calculation refers to the transit of May 14.

1706, May 24.

10	51	29	L'étoile entre dans le bord de la ☽. La lune se couvre l'étoile.	
11	3	53	pend. inf.	10 51 39 (sic)
11	0	0	pend. supr.	3 53

10 47 46
3 48
10 51 34

Transits and calculations for clock.

May 23	⊙	11° 55′ 50″		58′ 6″	56′ 58″		
24	⊙	55 32		57 49	56 40—20	56 20	midy.
24	|☾	9 52 41				3 40	
	L'étoile	9 55 39					
25	|☾	10 34 43	☽|	10 36 49		9 55 39	
26	⊙|	11 57 10				20	
		1 8				9 55 19	
		11 56 2				3 48	
		20				9 59 7	
		11 55 42					
Aug. 1	⊙	11 54 52		57′ 6″			

11 59 30	pend. supr.	
11 44 5	pend. infr.	
15 25		
8 26 30		
2 53 11		
6 26 41		
3 13 20½		
11 39 50½		
10		
11 40 0½		
15 25		
11 55 25	midy à la supr.	
11 55 59		
34	déclinaison.	

Altitudes ⊙ Aug. 1.

8 26 30	2 53 11	40 50
28 38	51 4	41 10
33 2	46 38	41 50
35 8	44 32	42 10

1706, Nov. 18 a. m., 17½ ast. time.

0 11 59	pend. inf. L'étoile se cache de derrière la ☽ en ligne droite avec Copernic et . . .
0 17 30	pendule sup.
0 18 25	pendule inf.
0 55	

Nov. 16	⊙ tr.	11 58 43	1′ 1″		11 59 52
					30
					11 59 22
17	|☾	9 52 25	54 35	le vent.	
19	⊙	11 58 17			11 59 26
					34
					11 58 52 midy.

Sept. 19	11 58 35	0 43	11 59 39	
			11 59 4	from alt.
			35	decl.
Alt. ⊙ Sept. 19, 1706.	9 27 24	2 30 6	33 0	
	31 40	25 53	33 30	
	35 57	21 36	34 0	
Dec. 5, 1706.	9 39 40	2 18 3	12 40	
	43 35	14 13	13 0	
	47 23	10 19	13 20	

1707, April 4.

8^h 8′ 1″ pendule supr. La petite étoile ρ d'Aries est cachée par le bord obscure de la lune.
add 10 6

9 7 41	pend. inf.	Apr. 1		51 51½	54 1
8 54 0	pend. sup.	3	⊙ tr.	11 50 28½	52 48
		4		49 43	51 52
13 41		5		48 57	51 6

Apr. 4. Alt. ⊙.

9 33 11	2 7 41	38 10	9 33 11	
36 7 dub.	4 49	38 30	2 7 41	
38 59	1 53	38 50	4 34 30	
41 57	1 58 56	39 10	2 17 15	
			11 50 26	
			16	
			11 50 10	
			11 50 47½	
			37	diff. declinatic.

1707, June 18	⊙ 11 55 8	57 25	56 16½
19	54 53	57 11	56 2
20	54 37	56 55	55 46

June 19. Altitude ⊙.

9 2 37	48 26	48 0
4 48	46 17	48 20
7 0	44 5	48 40
9 11	41 54	49 0
11 23	39 41	49 20
13 36	37 29	49 40

From all which he seems to deduce a correction of — 30″ for his instruments.

1707, Sept. 3. Occultation of Antares.

7^h 45′ Antares entre dans la partie obscure de la lune pend. inf. Cette immersion n'a été observée qu'a quelques secondes près.

8 33 11 Antares sort de la partie claire de la lune par la lunette de Campani, exacte.

Then come the following calculations:

8^h 50′	l'horl. sup.	7^h 45′		8 33 11	
8 52 57	l'horl. inf.	5 30½		5 30	
		13½		15	
		7 50 44		8 38 56½	
		2 57	à retr.	2 57	à retr.

7 47 47 heure vér. de l'imm. d'Antares.
8 36 0 heure vérit. de l'émers.

Transits of ⊙.

Aug. 29	11 57 25	59 34	58 29.5
30		58 55	
31		58 18	
Sept. 1		57 36	
3	11 54 3	56 12	55 7½
5	58 40	0 48	59 44
6	57 56½	0 5	59 0.8
7	57 12	59 20	58 16

Altitudes ⊙ Sept. 6.

9 31 23	38 0	2 24 58
34 9	38 20	22 11
36 48	38 40	19 28
39 37	39 0	16 38
42 26	39 20	13 49

No statement when the clock was put forward.

The authors of this "register" sometimes failed to apply any correction for motion of the sun to their corresponding altitudes.

The clock seems to have been put forward six minutes before the transit of the sun on September 5. Subtracting this, the clock-corrections from the transits are:—

	Sept. 3.	Sept. 5.
Clock-times of transit by quadrant . .	$23^h\ 55^m\ 7\frac{1}{2}^s$	$23^h\ 53^m\ 44^s$
Corrections of quadrant	$-\ 36\frac{1}{2}^s$	$-\ 37^s$
Clock-times of true transit	$23^h\ 54^m\ 31^s$	$23^h\ 53^m\ 7^s$
Mean times	$23^h\ 59^m\ 15^s$	$58^m\ 36^s$
Clock-corrections	$+\ 4^m\ 44^s$	$+\ 5^m\ 29^s$

Subtracting $2^m\ 57^s$ for reduction from one clock to the other, the times of the phases are:—

	Immersion.	Emersion.
Clock-times of occultation of Antares, 1707, Sept. 3,	$7^h\ 42^m\ 3^s$:	$8^h\ 30^m\ 14^s$
Clock-corrections	$+\ 4^m\ 51^s$	$+\ 4^m\ 52^s$
Paris mean times	$7^h\ 46^m\ 54^s$:	$8^h\ 35^m\ 6^s$
Greenwich mean times	$7^h\ 37^m\ 33^s$:	$8^h\ 25^m\ 45^s$

The first time may be considered as affected with a probable error of at least 10^s.

1708, Feb. 23, p. m. Occultation of Venus.

7 0 31 ♀ commence à entrer à la pend. inf. Lunette de 34.
0 46 Elle entre entièrement dans la lune.
7 0 23 ♀ commence à toucher la lune par la lunette de 34.
0 38 Vénus entre entièrement à la lunette de 34 et de 12 pieds.
add 3′ 19″
7 16 0 pend. supr.
7 16 9 pend. inf.
9

Feb. 21	⊙ tr.	11 57 45	59 57
22		57 4	59 15
23		56 20	58 33
24		55 38	57 50
25		54 49	57 1

Feb. 24. Alt. ⊙.

9h 42′ 45″	10′ 6″	24° 50′
46 8	6 39	25 10
49 42	3 13	25 30
53 16	59 35	25 50
56 53	1 55 17	26 10

1708, Sept. 6.

9 32 51	Emersion de χ Taureau de la partie obscure de la lune.
10 7 0	pendule inf.
10 7 0	pendule supr.
0 0 0	

Sept. 3	☉ tr.	11 57 15	59 24	11 58 19½	
				34	
				11 57 45	midy.
4		11 56 19	58 29	11 57 24	
				34	
				11 56 50	midy.
5		11 55 22	57 31	11 56 26	
				34	
				11 55 52	midy.
	7 a. m. ☽| cent.	5 14 23½	15 42½		
7	☉ tr.	11 53 27	55 36	11 54 31½	
				34	
				11 53 57½	
July 9	☉ tr	11 57 58½	0 16		
Sept. 12		11 58 14½	0 23		

1708, July 9. Alt. ☉.

9^h 37′ 4″	19′ 57″	51° 50′	11 58 31½	
39 27	17 36	52 10	7	
41 51	15 13	52 30		
44 17	12 50	52 50	11 58 38½	
46 41	2 10 23	53 10	11 59 6¾	
			28	decl. ad. occid.

Sept. 12.

9 30 52	26 0	35 40
33 48	23 13	36 0
40 38	2 16 5	36 50
43 33		37 10
46 31		37 30½
49 29		37 50
52 35		38 10
55 38		38 30

1709, April 20.

7^h 52′ 49″ Immersion dans la lune de l'étoile τ de la Lion. Pend. infér.

				Apr. 19, a. m.	
10 18 30	pend. inf.	10 51 31	pend. inf.	4 30 10	p. inf.
10 11 0	pend. supr.	44 0	pend. supr.	4 24 0	p. sup.
7 30		7 31		6 10	
				5 2	
				1 8	

		❘☾	☽❘	
Apr. 17	⊙ tr.	11 55 19	57 29	
18		—	56 51	11 55 46
19			56 11	32
				11 55 14
20		11 53 22	55 33	11 54 28
21		11 52 45	54 55	32
				11 53 56 midy.
23		11 51 34	53 45	11 52 39
				32
				11 52 7
				30
				11 51 37

1709, September 17 (or 16½ probably).

$0^h\ 6'\ 33''$ à l'horl. inf. Immersion de l'étoile σ de la 5e grandeur dans la partie obscure de la lune. Elle étoit en ligne droit avec Hélion et Timarchus.

0 23 51	l'horl. inf.
0 13 0	l'horl. sup.
10 51	

1709, Dec. 24.

9 45 44		12° 20′
49 47	2 4′ 50″	12 40
53 59	0 43	13 0
58 15	56 27	13 20

Sept. 15	⊙ tr.	11 49 22	51 30	
16		11 48 27	50 36	
13		51 13	53 22	
14		—	52 27	
16	❘☾	10 24 3	26 2	(Chord qui manque.)

La pendule supérieure s'est arestée.

		☽❘		
Dec. 24		11 59 4		11 57 53
				57 21
				32 decl.
1710, Feb. 9	11 51 10	53 24		11 52 17
July 22	11 56 27	58 43		11 57 35
				11 57 3
				32

1710, Feb. 9.

9 14 13	29 47	17° 50′
17 25	26 33	18 10
20 37	23 23	18 30
23 54	2 20 6	18 50

1710, July 22.

9 16 19	37 34	47 30
20 51	33 0	48 20
25 32	28 23	48 50
30 14	23 39	49 30
35 0	2 18 55	50 10

1709, Sept. 23. Occultation of Pleiades.

8 24 52	Maia entre dans la lune, lunette de 17 p.	pend. infér.
28 53	Taigeta entre lunette de 34 pieds.	pend. infér.
28 54	Taigeta entre lunette de 17 p.	pend. infér.
8 38 34	pendule inf.	
36 0	pendule supr.	
2 34		
8 47 44	L'étoile marquée χ entre	lunette de 17 p. pend. inf.
9 11 51	L'étoile χ sort	lunette de 17 p. pend. inf.
9 14 24	Maia sort	lunette de 17 p. pend. inf.

Sept. 20	⊙ tr.	11 58 28	0′ 36″	11 56 50
23		11 55 46	57 54	34
				11 56 16 midy le 22d.

1710, Dec. 4. Occ. Pleiades.

4 50 12 Electra entre dans la lune.
7 36 retard horl. sup. ab. hor. var.?
6 12
———
1 24 add.

5 48 22 L'étoile proche d'Asterope cache par la grande lunette.
5 56 58 Asterope entre dans la lune par la grande lunette.
6 9 50 ✳ sort.
23 28 Maia sort par le g. lunette.
———
6 59 9 pend. inf.
53 0 pend. supr.
———
6 9

Dec. 2	⊙ tr.	11 51 59	54 21	
3	" "	11 51 55	54 16	
3	☾ "	9 56 58	59 4	
4	⊙ "	11 51 50	54 12	
4	☾ "	4 59 45	5 1 58	
5	⊙ "	11 51 53	54 5	
Sept. 13		11 53 43	55 52	$D, -39^s$

Alt. ⊙ Sept. 13.

9 29 6	18 41	35° 50′
31 54	15 48	36 10
34 45	12 51	36 30
37 41	10 4	36 50

Dec. 4.

9 47 32	1 57 2	14° 0′
51 44	—	14 20

11 52 17 + 8 = 11 52 25

1711, Oct. 1. Occ. Pleiades (Oct. 0.6 astron. time).

	3 40 11	Maia est cachée par la lune	46′ 40″
add 6′ 29″			
	48 10	Taigeta est cachée par la lune	54 39
	4 50 55	Alcione est cachée par le bord clair de la lune . . .	57 26
6 31			
	4 56 18	Maia sort	5 2 49
	5 34 23	Alcione sort	40 55
6 32			

Sept. 27	⊙ tr. 11 55 53	58′ 3″	
28	11 55 5	57 16	
29	—	56 26	
Oct. 0.6	Le ventre de la ☽	2 53 30	
	☽|	55 26	
Oct. 2	11 51 56	54 5	
Sept. 15	11 50 28½	52 38	

Alt. ⊙ Sept. 15.

9 36 52	2 4 26	36° 30′	
40 0	1 24	36 50	
42 53	58 28	37 10	Corr. + 17.
45 59	55 19	37 30	
49 9	1 52 5	37 50	

Oct. 2 11 53 0
32
———
11 52 28 midy.

He seems to have used the same clock with which the transits of the ⊙ are observed.

1712, May 15½.

11 22 2 Immersion dans la partie obscure de la lune du ε Lion. Pend. inf.

Auf. 25″

0 1 15 Emersion de la partie claire.

11 26 2 pend. inf.

11 27 0 pend. sup.

		|(	)|	
May 13	⊙ tr.	0 0 29	2 42	0 2 4
15		0 0 57	3 11	32
17		—	3 44	——
18		0 1 45	4 0	0 1 32

"Le 19 May à 5^h du matin Mad. Cassini est accouchée d'une fille qui a été baptisée le 27 et nommée Susanne Françoise", which perhaps accounts for our having no corresponding altitudes since last September.

1714, Jan. 19, p. m.

5^h 46′ 18″ pend. inf. Immersion dans la partie obscure de la lune d'une étoile des Poissons.

6 34 0 l'étoile sort de la partie claire de la lune.

55 10 une autre étoile, beaucoup plus petite, entre dans la partie obscure de la lune vers son bord sept. qu'elle rase presque.

1714, Mar. 21.

10 14 41 pend. sup. une étoile *o* (Tauri, cornu) entre dans la ☽.

3 28

10 18 9

			Corr.	⊙ Alt. Mar. 16.		
Mar. 19	11 56 36	58′ 46″	−38″	9 27 21	28 27	30 10
20	56 24	58 33	−38	34 44	21 7	31 0
21	56 11	58 20½	−39	39 26	16 35	31 30
22	56 0	58 10		43 55	2 12 3	32 0
				Mar. 20.		
				8 55 36	2 58 42	27 40
				58 10	2 56 8	28 0

1714, Apr. 7, a. m. (6.6 ast.).

3 24 11 Immersion of ξ Sagittarii (bright limb) pend. supr.

or 3 24 12

add 9″

4 37 27 L'étoile sort de la partie obscure.

add 10″

		|(			Apr. 10, ⊙ limb. supr.	
Apr. 5	⊙ tr.	11 52 46		(+ 1′ 6″) (cl. adv. 7′)		
6			0 1 43	(− 1′ 5″)		
8		11 59 6½	61 15		6^h 14′ 14″	4° 0′ 0
					17 26	3 30
9		11 58 56	—		20 40	3 0
					23 55	2 30
10			60 52		27 15	2 0
					30 27	1 30
11		11 58 32	60 42		34 8	1 0

At noon, T. 54°.1; barom. 27 11¾.

1715, July 22, a. m., Occ. of *q* (?) Piscium (21.6 ast. time).

	2h 53′ 26″	Immersion en la bord claire.
auf. 0′ 9″		
	2 53 17	
	3 46 13	J'ay commencé de voir l'émersion de l'étoile obscure. L'étoile étoit encore assez sensible quoiqu'il fit grand jour.
	3 46 4	

					⊙ Alt. May 26.	
May 26		0h 0′ 53″	|(			
July 20	⊙ tr.	11 59 33	1 48	9 36 56	26 9	50 20
21		59 37	—	39 17	23 46	50 40
22		59 40	1 56	41 42	2 21 22	51 0
				44 9	18 56	51 20

1715, Aug. 15 (+ ½ ast.).

				⊙ Alt. July 26, 1715.	
	11 54 29	l'étoile χ du Verseau entre dans la lune.	9 39 27	20 59	49° 40′
			43 7	17 19	50 10
sub. 2′ 37					
	11 58 12	pend. inf.	46 51	2 13 37	50 40
	11 54 0	pend. sup.			
	0 39 36	émersion de l'étoile χ.		Sept. 16.	

July 26	⊙ tr.	11h 59′ 52″½	2′ 7″½	9 34 42	18 55	35 10
Aug. 9		11 59 10	1 22	38 51	14 36	35 40
10		11 59 1	—	43 13	10 11	36 10
16		11 57 51	60 3	47 49	5 39	36 40
Sept. 15		11 57 1	59 8	52 29	1 0	37 10
16		11 36 39	—			
17		—	11 58 26			

1715, Oct. 9, p. m.

8h 17′ 2″ l'étoile venoit d'entrer dans le bord obsc. de la lune. Pend. inf. Lunette de 17 p.
8 24 22 pend. inf.
8 23 0 pend. sup.

1 22

					⊙ Alt. Nov. 3.	
Oct. 6	⊙ tr	—	60 37	9 50 44	9 23	20 20
7		11 58 14	—	9 56 10	2 3 43	20 50
10		11 57 30	59 39	10 0 0	59 51	21 10
Nov. 3		11 59 43	1 58	4 2	1 55 51	21 30

Dec. 30, p. m.

7h 28′ 1″ pend. sup. Immersion de l'étoile χ du Verseau.
7 23 37 pend. inf. Immersion de l'étoile χ.
7 25 39 pend. inf.
7 30 0 pend. sup.

Dec. 23	⊙ tr.	0 0 15	2 39
30		0 3 26½	5 48
1716, Jan. 7		0 6 48	—
10		0 7 59	10 20

1717, Sept. 25. Occult. of Aldebaran, à la pendule inférieure.

	9 13 46	Aldebaran est caché par la lune.		
sub. 2′ 14½″				
	9 20 18	pendule inférieure.	10 52 21	signal pend. inf.
	9 16 0	pendule supérieure.	10 48 0	pend. sup.
	4 18			
auf. 2′ 16″				
	10 6 ⁵⁄₃ 9	Aldebaran sort du bord obscure tout d'un coup.		

Sept. 24	⊙ tr.	11 58 2	—	corr. — 41″
25		11 57 41	59 50	— 41″
26		11 57 17½	59 25	
Dec. 19		0 0 1	2 24	
Sept. 20		11 55 41	57 49	

1717, Dec. 19, Alt. ⊙.

9 53 7		12 40
57 26	3′ 55″	13 0
10 1 38	59 36	13 20
6 4	1 55 9	13 40

1717, Sept. 20.

9 41 23	10 13	34 30
44 31	7 10	34 50
48 6 dub.	4 1	35 10
50 44	0 51	35 30

No records for the first five months of 1718.

1719, April 22, p. m.

	7 42 37	Immersion d'Aldebaran dans la lune à la vue et en mesme temps avec la lunette.
add	1 55	
	7 44 32	
	8 32 11	Aldebaran sort du bord clair de la lune.
	1 56	
	8 34 7	
	8 34 58	Aldebaran sort et on l'apperçoit dans l'instant.
	8 37 0	la pendule.
	8 39 52	pend. inf.
	2 52	

1718, Sept. 26	⊙ tr.	59 29	1 38	
27		59 6	1 15	
28		58 39	0 48	
1719, Apr. 22		11 57 44	59 55	corr. — 42ˢ
23		57 22	59 33	— 41

⊙ Alt. Sept. 27, 1718.

9 48 19	2 9 58	32° 30′
51 31	6 46	32 50
54 45	3 33	33 10

1719, Oct. 30, Occ. of Aldebaran.

9 58 57 à la pendule sup. Aldebaran sort du bord obscure.

add 0′ 13″

		☾			
1719, Oct. 29	⊙ tr.	11 59 43	1′ 57″	0 0 50	
30			1 40	40	
Nov. 3	☽ (?)	0 30 0	32 13		
6		11 57 59	0 15	0 0 10	midy.
Nov. 3		8 3 58	— du Verseau au fixe.		
Nov. 26		7 14 30	l'étoile γ entre dans le disque de la lune claire l. 7½ p.		
		7 14 54	l'étoile γ entre dans la lune par la lunette de 17 p. après avoir paru quelques seconds sur le bord.		
		7 18 1	pend. inf.		
		18 0	pend. sup.		

	|(	)|	1720, May 21, Alt. ⊙.		
1709, Nov. 24	11^h 57′ 13″	59′ 32	9 31 57		49 10
25	—	59 36	35 31		49 40
26	57 22	59 42	39 4	2 21 28	50 10
27	57 28	—	42 41		50 40

1720, April 21, a. m. (20.5 ast.).

				1720, May 28.	
0 22 14	pend. inf.	Imm. γ^1 Virginis.	9 42 34 op.	2 15 34 op.	51 50
0 22 44		Em. de γ^2 Virginis.	46 14 op.	—	52 20
0 48 16	Emersion des deux étoiles du bord clair.		49 32	—	52 49 30
			53 35	—	53 19 20

0 25 48	pend. inf.	Apr. 16	⊙ tr.	11 58 46	0 57
0 26 0		20		—	59 12
——		23		11 55 45½	57 56 c, —42″
0 12		May 19		11 59 2	1 17½—j'a jouté 1′ à la pendule.
0 55 49	pend. inf.	21		59 37	1 53
0 56 0		28		58 28	0 43
——					
0 11					

1718, Sept. 9.

8^h 45′ 44″ L'étoile disparoit au bord de la lune—pend. sup. de la tour.

auf. 9″

10 9 33 pendule inf. de la tour.

10 9 0 pendule sup. de la tour.

33

Dans la tour inférieure. (La pendule retardoit de une minute 6 secondes à l'égard de celle de la tour sup.)

8 46 30 Une étoile des Poissons s'éclipse.

aus 43″

(I see nothing to reconcile the discrepancies between the clocks. Here is everything:—)

Sept. 7	⊙ tr.	11 54 46½	56 57½	
8		54 19	56 29	J'ajoute 6′.
10		11 59 30	1 38	

There was considerable difficulty in reducing these observations, but I think I have completely surmounted it. From the Memoirs of the Academy, 1718, it would seem that the first of the above observations is that of MARALDI, who gives $8^h\ 45^m\ 35^s$ for the apparent time, and hence must have applied -9^s for clock. It would, therefore, seem that this "pend. sup. de la tour" is the clock with which the sun's transit is regularly observed, the correction of which, on mean time, is $-3^m\ 6^s$. We have, therefore, $8^h\ 42^m\ 38^s$ for the mean time of occultation from MARALDI's observation. The equation of time being $-2\ \ 57^s$, this result agrees exactly with MARALDI's as published.

The lower clock used by CASSINI being 33^s ahead of the upper one, its correction on apparent time would be -42^s. He writes 43^s, so that this hypothesis is probably correct. But he actually applies 50^s, seemingly out of carelessness with regard to the

units of seconds, and thus obtains his printed result $8^h\ 45^m\ 40^s$. Supposing, then, a difference of 33^s between the clocks, the correction on mean time would be $-3^m\ 39^s$, and the mean time of occultation would be $8^h\ 42^m\ 51^s$. The occultation was observed also by LA HIRE, and the three results are:—

MARALDI	$8^h\ 42^m\ 38^s$.
LA HIRE	$8^h\ 42^m\ 44^s.1$
CASSINI	$8^h\ 42^m\ 51^s$.

I am inclined, under these circumstances, to use LA HIRE's observation only. The moon was totally eclipsed, and the occultation took place at a considerable angle, so that the results with respect to the phase of the moon are not so discordant as the times would indicate.

1727, Sept. 7. Occultation of Pleiades.

$2^h\ 3'\ 7''$	L'ét. des Pleiades entre dans le bord clair avec une l. d. 15 p.		
2 3 4	avec la lunette de Angleterre.		
3 5	" " " $6\frac{1}{2}$ p.		
2 8 56	L'ét. des Pleiades. On n'a pas pu la voir avec les 2 autres lunettes.		
2 41 50	L'ét. la plus septentrionale entre		
47 ou 48 par la lunette de Angleterre.			
2 44 1	L'ét. la plus mérid. entre.		
2 44 0	Lunette de Angleterre.	2 48 13	pend. inf.
		2 36 0	
2 43 58	par la lunette de $6\frac{1}{2}$ p.		
3 11 58	Émersion de l'étoile que je crois la 1[er].		
22 22	Emersion de celle que je crois la 2[e].		
37 40	Emersion de celle que je crois la 4[e].	4 11 12	pend. inf.
4 2 20	Emersion de celle qui est la plus méridionale.	3 59 0	p. sup.

1727, Mar. 19	⊙ tr.	11 48 27	50′ 36 aj. 12 à la p.		1727, Mar. 21.	Alt. ⊙.	
20		59 31	1 42	8 53 8	27 20	3 5 37	11 59 $22\frac{1}{2}$
21		58 $39\frac{1}{2}$	0 49	58 7	28 0	0 37	$18\frac{5}{6}$
23		—	59 $6\frac{1}{2}$	0 42	28 20	2 58 4	———
Sept. 5		11 48 $15\frac{3}{4}$	50 25	5 48	29 0	52 55	11 59 $3\frac{5}{12}$
6		47 39	—				11 59 $44\frac{1}{4}$
8		46 9	48 57*				———
11		43 $46\frac{1}{3}$	45 55			Decl.	$40\frac{10}{12}$
1728, Feb. 13		11 52 38	54 52				
Aug. 30		12 48 $12\frac{1}{2}$	50 22		1728, Feb. 13.		
				9 47 0	1 59 38		22° 0′
					1728, Aug. 30.		
				10 30 $24\frac{1}{2}$	47 45		0 57 16:
				42 $50\frac{1}{2}$	48 0	Un peu à gauche du centre.	
				46 $46\frac{1}{2}$	48 15		
				50 46	48 30		0 45 52:

The following table is given on the first page of volume 36, which contains the observations of 1732–33. It seems to be derived principally from observations in 1733 not found in the record, but this is not certain. I give the table in the order in which it is found.

Déclinaison du quart du circle fixe qui est dans la tour occidentale sup. à l'égard de la méridienne.

Hauteurs.			
18°	40	sec. al. occ.	These first four in a different handwriting from the others.
19	40½		
20	40½		
21	42		
24 50′	43		
55	44		
54 54	43		
38	43		
33 37	43		
23 54	41		
10 13	41		
18	40		
18	39¼		
18	38½		
30	42		

If this table refers to the instrument with which the sun's transits were commonly observed, the numbers would seem to be too great for use in previous years. But it confirms the suspicion of an increase in the error of the quadrant.

1738, Jan. 2. Occultation of Aldebaran.

9 45 7 ou 8, clock. Aldebaran entre—partie obscure 9 39 51 app. time.
5 16 sub.
11 6 24 Aldebaran sort. 11 1 6 app. time.

Jan. 1	⊙ tr.	0 2 46½	5′ 9″		4 52″	Midy à la pendule.
2		0 3 41	—		4 54	Midy vray.
3		0 4 36	6 57		5 46½	Midy pend. inf.
					10 37	
Jan. 2	☽ I	9 29 54½				
		1 4½			16 23½	
					2	
		9 30 0				
Aldebaran tr.		9 32 14	5 13	subtr.	16 25½	Midy. pend. sup.

1738, Dec. 23. Occult. of Aldebaran.

5 50 35	Immersion partie obscure.	Dec. 19	⊙ tr.	0^h 12′ 53″	15′ 15″½
16 28½		20	⊙	0 13 27	15 49
5 34 6½	Immersion heure vraye.	23	⊙	15 7½	17 29½
			Aldeb.	10 28 51	
6 50 36	Emersion.		☽	10 34 0	
—16 30					
		24	⊙	0 15 41	18 3
6 34 6	Emersion heure vraye.				

A great gnomon was established in the year 1729, and it may be that the transits of the sun were observed over it after that date, but I am by no means sure. A correction of $+2^s$ is, however, applied for error of meridian, and it seems to be well determined, though I do not know how.

1739, Feb. 15 6 50 32 Imm. of *ο* Tauri Clock 5′ 1″ App. time 6 45 31
Feb. 13 noon by 5 good corresp. altitudes . . . . 0° 4′ 57″.3
16 per gnomon, uncorrected . . . . . . 0 4 58.7 Corrected 0 5 0 .2

1755, July 6, a. m.

4 38 53 Immersion of Aldebaran, 3 telescopes.
— 6 51

⊙ tr.	July 4		0 10 $23\frac{1}{2}$	12 $40\frac{1}{2}$	
	5		5 34	7 $50\frac{1}{2}$	
	6		5 $43\frac{1}{2}$	8 $0\frac{1}{2}$	
	9		6 12	8 $28\frac{1}{2}$	
	16		6 $54\frac{1}{2}$	9 11	
	July 16	Arcturus	6 30 8		
	17	Arcturus	6 26 10.8		
	18	Arcturus	6 22 13.5		
		☽	7 53 25.8		
	19		0 7 6	9 $21\frac{1}{2}$	

Corrections to "Mural" per corresp. alts.

1755, Jan. 23	— $6^s.2$
Apr. 15	— $0^s.7$
Apr. 21	+ $0^s.3$
May 5	+ $0^s.6$
May 26	+ $1^s.5$

July 18. Corresp. alts.

9 2 43	3 8 31.5
14 18.5	1 57.5

1755, July 18 9^h 15′ 17″ Imm. θ Libræ per 3 observers.

1757, Feb. 25, p. m.

6 53 57 Immersion of Aldebaran.
8 11 29 Commencement de l'émersion, il fait une échancrure au bord éclairé de la lune, et a esté plusieurs secondes sans se séparer de la bord de la lune, ce qui nous a fort étonné Mr. de Thury et moy.
11 39 Il est totalement séparé.

Feb. 24	⊙ tr.	0^h 18′ 26″.5	20′ 38″.5	9 10′ 29″	8° 0′	3° 8′ 18″	
25		18 12	20 32	13 35	8 20	3 5 $4\frac{1}{2}$	
26		17 57	20 8.7	16 $46\frac{1}{2}$	8 40	3 1 54	
				20 3	9 0	58 $41\frac{1}{2}$	
				23 20	9 20	2 55 $18\frac{1}{2}$	
				26 41	9 40	2 52 0	
				30 $4\frac{1}{2}$	10 0	2 48 41	

(The last four columns are headed: 1756, Dec. 13.)

1756, Dec. 13, a. m.

4 33 44	imm.	ε ♌	— 9 16	4 24 28	Duree 1 20 50 } Copy complete and literal.
5 54 35	emersion		— 9 17	5 45 18	

1756, Dec. 17.

Dec. 12	⊙ tr.	0 7 58	10 21.5					
13	a. m. Regulus	— —	— —	4 40 52.5	9 7 $15\frac{1}{2}$	7° 20′		
13	⊙	8 20	10 42.5		10 20	7 40		
15	⊙	9 6	—		13 $30\frac{1}{2}$	8 0		
16	⊙	9 30.5	11 53		16 $40\frac{1}{2}$	8 20		
17	⊙	9 54.5	12 16	Décl. 8″ soust.	19 $53\frac{1}{2}$	8 40	2′ 1″	

1758, Feb. 17.

10 36 25 Immersion of γ Geminorum.

Feb. 15	⊙ tr.	0 3 $14\frac{1}{2}$	5 28		9 47 52	14 10	2 56 20	bonne.
16		3 $52\frac{1}{2}$	6 6		51 14	14 30	2 52 57	med.
17	☾	8 9 $6\frac{1}{2}$	10 51 (le ventre)		54 41	14 50	2 49 33	assez bonne.
	γ Gem.			8 14 $59\frac{1}{2}$			0 22 $7\frac{1}{2}$	
18	☾	8 59 $2\frac{1}{2}$					— 13	
19		0 5 $42\frac{1}{2}$	7 $55\frac{1}{2}$					
Jan. 23		0 20 47	23 $6\frac{1}{2}$				0 21 $54\frac{1}{2}$	
24		20 $52\frac{1}{2}$	23 $11\frac{1}{2}$				22 2	

(Columns 6–8 headed: Jan. 24, 1758.)

Decl. mural (?) $7\frac{1}{2}$

SERIES V.

Observations by DELISLE *at St. Petersburg.*

These observations have never been published. The original manuscripts were retained by DELISLE when he returned to Paris about 1749, and were eventually deposited at the Paris Observatory. In 1844, they were claimed by the Russian Government, delivered to OTTO STRUVE, and deposited at the Pulkowa Observatory. A full report upon them was made by STRUVE, who called attention to the possible value of the observations of occultations of the Pleiades which they contained. These occultations were discussed by LINSSER in 1864, who compared the observed times with those computed from HANSEN's Lunar Tables, showing a good agreement.

Desirous of including in the present investigation all that was valuable in DELISLE's observations, I took occasion, during a visit to Pulkowa, in March, 1871, to ask STRUVE's permission to examine the manuscripts, and make extracts for the purpose in view. This was very kindly granted, and the services of the secretary of the establishment, Mr. LINDEMANN, were placed at my disposal while engaged in the examination of this and the other treasures of astronomy which are contained in the library of the Observatory. I retain a very pleasant recollection of Mr. LINDEMANN's courtesy in rendering this assistance.

The extracts from DELISLE's manuscripts are given quite fully in the following pages. The reduction of the observations has given some trouble, owing to the multiplicity of clocks, and the varying and irregular manner in which the time and other observations were made The general system of observation was the same as that pursued in Paris, the transits of the sun over the meridian of a gnomon being observed quite regularly, and the error of the gnomon being determined from time to time by corresponding altitudes of the sun before and after noon.

Place of observation, Observatoire Impérial en Basile Ostrow.

1727, le 21 février, nouv.

Hauteurs du soleil pour l'horloge.

Matin.	Hauteurs.	Soir.		
$3^h\ 28^m\ 20^s$	$13^\circ\ 16'$	$2^h\ 38^m\ 30\frac{1}{2}^s$		
34 51	13 46	32 $1\frac{1}{2}$	Milieu	$0^h\ 3^m\ 26^s$
37 $8\frac{1}{2}$	13 56	29 43	Correct. de Nadius soust. .	28
39 $21\frac{1}{2}$	14 6	27 $28\frac{1}{2}$	Midi vrai	0 2 58
41 44	14 16	25 9		
44 2	14 26	22 $52\frac{1}{2}$		

Le 26, hauteurs du soleil pour l'horloge.

$9^h\ 14^m\ 17^s$	$13^\circ\ 56'$	$9^h\ 28^m\ 23^s$	$15^\circ\ 6'$
16 13	14 6	30 30	15 16
18 17	14 16	32 44	15 26
20 17	14 26	35 1	15 36
22 19	14 36	37 9	15 46
24 19	14 46	39 13	15 56
26 $21\frac{1}{2}$	14 56		

Le 27 février.

Le soir à $8^h\ 42^m\ 12^s$ de la pendule immersion dans la partie obscure de la lune d'une forte petite étoile de la queue du Bélier. Il y avait 2 autres étoiles plus considérables situées ainsi . . .
Le temps vrai de cette immersion déduit des midis le 21 et 28 février est à $8^h\ 40^m\ 53^s$.

Le 28 février.

Hauteurs du soleil pour l'horloge.

Matin.			Hauteurs.		Le soir.			Milieu.		
9ʰ	9ᵐ	29ˢ	14°	16′	2ʰ	53ᵐ	46ˢ	0ʰ	1ᵐ	37½ˢ
	11	26	14	26		51	48½	0	1	37¼
	13	23	14	36		49	51½	0	1	37¼
	15	19	14	46		47	56	0	1	37½
	17	16	14	56		46	0	0	1	38
	19	11	15	6		44	5	0	1	36
	21	12	15	16		42	0	0	1	36
	23	20	15	26		39	53½	0	1	36¾
	25	27	15	36		37	47	0	1	37
	27	31½	15	46		35	43	0	1	37¼
	29	27	15	56		33	46½	0	1	37

Milieu sans correction . .	0ʰ	1ᵐ	37ˢ
Correction de Nadius soust.			— 28
Midi vrai	0	1	9
Midi vrai le 21	0	2	58
Différence pour 7 jours .		1	49

Hauteur mérid. du bord sup. du soleil 22° 17′ 15″ fort exacte.

Instead of depending on the clock-rate from the altitudes of February 21 and February 28, I have utilized those made on the morning of the 26th. By computing the altitude from the corresponding observations of February 21 and 28, it appears that the altitudes as given require a correction of $-16'.2$ for semi-diameter and index-error. Applying this, we have an error of clock on apparent time of $1^m\ 41^s.5$. We then find:—

	Clock Fast, App. Time.		Equation of Time.		Clock-correction.	
d h	*m*	*s*	*m*	*s*	*m*	*s*
Feb. 25, 21.4	1	41.5	+ 13	25.3	+ 11	43.8
28, 0.0	1	8.0	+ 13	0.4	+ 11	52.4

Interpolating to the time of the occultation, we find:—

Clock-time of occultation of α Tauri, 1727, February 27 . .	$8^h\ 42^m\ 12^s$.
Clock-correction	$11^m\ 49^s.8$
Local mean time	$8^h\ 54^m\ 1^s.8$
Greenwich mean time	$6^h\ 52^m\ 48^s.3 \pm 2^s$.

Occultations of the Pleiades, 1729, *December* 3.—These observations being given, *in extenso*, by LINSSER, in the paper already referred to, I made no copy of them, but only compared the original here and there with LINSSER's printed data. It seems sufficient to present those of the results most likely to give rise to questions. LINSSER gives the following results for correction of the time of sun's transit over the gnomon:—

1729, Nov. 23	$+1^s\ 5$
1730, Feb. 1	$+3^s.8$
1730, Mar. 4	$+8^s.2$.

But he makes no statement of the correction which he actually adopts, nor of his grounds for adopting it, only remarking that it is interpolated from the above values By calculating backward from his results for clock-error, and his tabular data, he would seem to have adopted $+1^s.0$. It would, therefore, seem that he considered the

correction to vary with the declination of the sun rather than with the time. But when the results for several years are placed together, they appear to vary only with the time. I therefore adopted $+2^s.5$ for the correction. The addition of a slight difference in the equation of time, arising from the periodic perturbations of the sun's longitude, being neglected in my work, carries the difference of computed mean times up to 2^s, an amount by which my mean times are less than those of LINSSER. The following are my independent results, alongside of which I place for comparison those of LINSSER. The results are a mean of those from the two clocks C and D, which differ between themselves by an amount varying from $1^s.4$ to $1^s.0$.

Date, 1729, *December* 3.

Star.	Local Mean Time of Occultation.	Linsser.	Sidereal Time.	Greenwich Mean Time.
	h m s	*s*	*h m s*	*h m s*
Electra .	16 35 57.9	59.7	9 27 24.9	14 34 44.4
Celæna .	41 39.6	41.5	33 7.6	40 26.1
Maja . .	17 16 56.6	58.8	10 8 30.3	15 15 43.1
Merope .	31 47.4	49.7	23 23.6	30 33.9
Alcyone .	48 13.8	15.6	39 52.7	47 0.3
Pleione .	18 32 17.4	19.7	11 24 3.5	16 31 3.9
Atlas . .	37 35.6	37.7	11 29 22.6	36 22.1

1733, le 22 Mars.

À midi vrai	C	11^h	$55'$	$17''$
	D	11	2	19
	N	11	57	59
	M	11	54	17

Le soir, occultation ν qui est dans un des pieds des Jumeaux. Immersion très exacte à $7^h\ 24^m\ 8\frac{1}{2}^s$. Pendule N avec plusieurs lunettes. Emersion à $8^h\ 30^m\ 20^s$ ± très incertaine.

Comparaison des pendules.

Immédiatement après l'immersion.			Immédiatement après l'émersion.		
$7^h\ 24^m\ 51\frac{1}{2}^s$	$6^h\ 31^m\ 0^s$	$7^h\ 27^m\ 41\frac{1}{2}^s$	$8^h\ 31^m\ 57^s$	$7^h\ 38^m\ 0^s$	$8^h\ 34^m\ 49^s$
7 25 $51\frac{1}{2}$	6 32 0	7 28 $41\frac{1}{2}$			
C	D	N	C	D	N

L'immersion est donc arrivée.

	Aux pendules.	Au temps vrais.	
C	$7^h\ 21^m\ 18\frac{1}{2}^s$	$7^h\ 26^m\ 10\frac{1}{2}^s$	La pendule N à ensuite été arrétée.
D	6 27 27	7 26 10	
N	7 24 $8\frac{1}{2}$	7 26 12	

Le 23 Mars.

À midi vrai	C	11^h	54^m	47^s
	D	10	58	59
	N	0	0	3
	M	11	52	38

Le 24 Mars.

À midi vrai	C	11	54	$27\frac{1}{2}$
	D	10	55	48
	N	11	54	$31\frac{1}{2}$
	M	11	53	7

Le 25 Mars.

À midi vrai	C	11	54	5
	D	10	52	32
	N	11	54	41
	M	11	50	29

Le soir, occultation de κ ♋ dans un instant à $7^h\ 15^m\ 44^s\tfrac{1}{2}$ de la pendule C.

	C	N	D	C
Après l'immersion	$7^h\ 18^m\ 0^s$	$7^h\ 18\ 44\tfrac{1}{2}^s$	$6^h\ 19^m\ 0^s$	$7^h\ 21^m\ 26^s$

L'immersion est arrivée.

	Aux pendules.	Au temps vrais.
C	$7^h\ 15^m\ 44\tfrac{1}{2}^s$	$7^h\ 21^m\ 47\tfrac{1}{2}^s$
D	6 13 $18\tfrac{1}{2}$	7 21 47
N	7 16 29	7 21 48

La pendule M à été retardée 27^s en la remontant et avancée 10 min. pour l'approcher du temps vrai.

Le 27 Mars à midy	C	11′	53″	12^s
	D	10	46	1
	N	11	54	42
	M	0	0	$42\tfrac{1}{2}$

Dans ces calculs du temps vrai il n'y avait point d'erreur à la méridienne.
(To determine the error of meridian.)

Le 20 Mars. Hauteurs du bord supérieur du soleil.

Pend. E, 8^h	23^m	17^s	18°	21′	3^h	15^m	67″	11^h	49^m	$37\tfrac{1}{4}^s$
	24	58	18	31		14	20			39
	26	36	18	41		12	42			$39\tfrac{1}{4}$
	28	14	18	51		11	1			$37\tfrac{3}{4}$
	29	55	19	1		9	21			38
	31	$32\tfrac{1}{2}$	19	11		7	43			$37\tfrac{3}{4}$
	33	11	19	21		6	4			$37\tfrac{3}{4}$
	34	$53\tfrac{1}{2}$	19	31		4	22			$37\tfrac{3}{4}$
	36	31	19	41		2	44			$37\tfrac{3}{4}$
	38	12	19	51	3	1	6			39
	39	51	20	1	2	59	25			38
	41	38	20	11		57	40			38

Milieu	11^h	49′	38″	11‴
Correction			29	39
Pend. E	11	49	8	32
Diff. pend. . . .	0	40	30	30
Pendule D	11	8	38	2
À la mérid. D . .	11	8	39	22
Correction de la méridienne . . .	—		12″	0‴

Le 28 Mars.

Uncorrected time of apparent noon from double altitudes with clock C	11^h	53^m	$14^s.7$
Correction of Euler		—	29.6
True noon per clock C	11	52	45.1
Difference of clocks at noon (D — C)	1	9	57.0
True noon by clock D	10	42	48.1
Transit of sun per clock D	10	42	48.7
Correction		—	0.6

The results for correction of gnomon are:—

1733, March 20 . . . . $-1^s.3$
March 28 . . . . $-0^s.6$.

The value $-1^s.0$ has been adopted. The corrections of the three clocks, C, D, and N, are then found to be as follows:—

		C	D	N
March 22.	At apparent noon,	$+11^m\ 47^s.3$	$+64^m\ 45^s.3$	$+9^m\ 5^s.3$
23.		$11^m\ 58^s.5$	$67^m\ 46^s.5$	$6^m\ 42^s.5$
25.		$12^m\ 3^s.0$	$73^m\ 36^s.0$	$11^m\ 27^s.8$
27.		$12^m\ 18^s.4$	$79^m\ 29^s.4$	$10^m\ 48^s.4$
28.		. . .	$82^m\ 22^s.5$	. .

We then have the following results for mean time from the three clocks:—

1733, March 22.

	C	D	N
Immersions of ν Gemin clock	$7^h\ 21^m\ 18^s.5$	$6^h\ 27^m\ 27^s.0$	$7^h\ 24^m\ 8^s.5$
Clock-corrections	$+\ 11^m\ 50^s.7$	$1^h\ 5^m\ 41^s.4$	?
Mean times	$7^h\ 33^m\ 9^s.2$	$7^h\ 33^m\ 8^s.4.$	. . .

1733, March 25.

Immersion of $\varkappa$ Cancri, clock	$7^h\ 15^m\ 44^s.5$	$6^h\ 13^m\ 18^s.5$	$7^h\ 16^m\ 29^s.0$
	$+\ 12^m\ 5^s.3$	$1^h\ 14^m\ 30^s.2$	$11^m\ 21^s.2$
	$7^h\ 27^m\ 49^s.8$	$7^h\ 27^m\ 48^s.7$	$7^h\ 27^m\ 50^s.2.$

The mean of the times given by the several clocks will be adopted.

1736, April 14. Transit of sun's centre, clock A, $1^h\ 32^m\ 11\frac{3}{4}^s$.

Comparison of clocks	M	1^h	38^m	0^s
	A	1	35	17
	N	1	52	43

Immersion of Aldebaran instantaneous at M, $11^h\ 56^m\ 30^s$.

Afterward	M	11^h	58^m	0^s
	A	11	55	5
	N	0	13	$24\frac{1}{2}$

"L'erreur de la méridienne est d'environ 7″ additive."

Times of the immersion.

	Pendules.			Temps vrai.		
A	11^h	53^m	35^s	10^h	19^m	$52\frac{3}{4}^s$
M	11	56	50	10	19	$55\frac{1}{4}$
N	0	11	$54\frac{1}{2}$	10	19	$58\frac{3}{4}$

April 15.	Sun on meridian	A	1^h	35^m	$25\frac{3}{4}^s$
		M	1	38	$37\frac{1}{2}$
		N	1	54	$54\frac{1}{2}$

Applying $+6^s.5$ for error of gnomon, we have the following results for clock-correction:—

		A	M	N
April 14.	Apparent noon	$-92^m\ 10^s.7$	$-94^m\ 53^s.7$	$-109^m\ 36^s.7$
15.	Apparent noon	$-95^m\ 40^s.0$	$-98^m\ 51^s.7$	$-115^m\ 8^s.7.$

The mean time of the observed occultation is then found from each of the clocks as follows:—

1736, April 14.

	A	M	N
Clock-times of imm. of α Tauri	$11^h\ 53^m\ 35^s.$	$11^h\ 56^m\ 30^s.$	$12^h\ 11^m\ 54^s.5$
Clock-corrections	$-1^h\ 33^m\ 40^s.7$	$-1^h\ 36^m\ 36^s.1$	$-1^h\ 51^m\ 59^s.7$
Local mean times . . .	$10\ \ 19^m\ 54^s.3$	$10^h\ 19^m\ 53^s.9$	$10^h\ 19^m\ 54^s.8.$

1736, June 20.

The correction of the meridian is found to be very accurately + 9.2^s, to be added to the observed times of transit of the sun.

Aug. 1.	Transit of the sun	A	8^h	45^m	34^s	
		M	8	41	58	
	Pendule nouvelle, afterward stopped		[8	48	40]	nouvelle.
			8	48	22	supérieure.
	Next morning immersion of Aldebaran very exact . . .	A	2^h	59^m	$9\frac{1}{2}^s$	
	emersion	A	4	10	59	

"Je crois qu'elle ne faisait que de sortir quand je l'ai aperçu car j'étais fort attentif et elle m'a paru d'abord fort brillant à l'endroit de la lune où je l'attendais."

Après l'immersion	M	2^h	58^m	0^s	Après l'émersion	M	4^h	9^m	0^s
	A	3	1	$40\frac{1}{2}$		A	4	12	39
	Sup.	3	4	26		Sup.	4	15	26

	Immersion. Clock.	Immersion. True.	Emersion. Clock.	Emersion. True.
A	2^h 59^m $9\frac{1}{2}^s$	[6^h 10^m 34^s]	4^h 10^m 59^s	[7^h 22^m 56^s]
M	2 55 29	6 10 $25\frac{1}{2}$	4 7 20	7 22 47
Sup.	3 1 55	6 10 $27\frac{1}{2}$	4 13 46	7 22 $48\frac{1}{2}$

Aug. 2.	* Sun on meridian . . . . clock	A	8^h	49^m	22^s
		M	8	45	50
		Sup.	8	52	15

I find no reason given for rejecting clock A, except its discordance.

Proceeding as usual, and adding + 9^s.2 for error of gnomon, we have the following results for correction of the three clocks, A, M, and Sup:—

	A.	M.	Sup.
Clock-times of transit, August 1 .	8^h 45^m $43^s.2$	8^h 42^m $7^s.2$	8^h 48^m $31^s.2$
Mean time	0^h 5^m $46^s.9$	. . . . .	. . . . .
Clock-corrections	15^h 20^m $3^s.7$	15^h 23^m $39^s.7$	15^h 17^m $15^s.7$
Clock-times of transit, August 2 .	8^h 49^m $31^s.2$	8^h 45^m $59^s.2$	8^h 52^m $24^s.2$
Mean time	0^h 5^m $42^s.9$	. . . . .	. . . . .
Clock-corrections	15^h 16^m $11^s.7$	15^h 19^m $43^s.7$	15^h 13^m $18^s.7$
Immersions of α Tauri, clock . .	2^h 59^m 9^s 5	2^h 55^m $29^s.0$	3^h 1^m $55^s.0$
Clock-corrections	15^h 17^m $8^s.0$	15^h 20^m $40^s.9$	15^h 14^m $16^s.2$
Mean times	18^h 16^m $17^s.5$	18^h 16^m $9^s.9$	18^h 16^m $11^s.2$
Emersions, clock	4^h 10^m $59^s.$	4^h 7^m $20^s.$	4^h 13^m $46^s.$
Clock-corrections	15^h 16^m $56^s.4$	15^h 20^m $29^s.2$	15^h 14^m $4^s.4$
Mean times	19^h 27^m $55^s.4$	19^h 27^m $49^s.2$	19^h 27^m $50^s.4$

In doubt whether to reject or retain clock A, I shall give it half-weight in taking the mean.

Occultation of Aldebaran Oct. 23, a. m., 1736.

Immersion very exact at bright limb	A	4^h	50^m	58^s
Emersion	A	6	6	1

". . . Quoiqu'il y eut un grand brouillard au traverse dequel la lune paraissait et qui empêchait de bien distinguer les taches; cependant ayant encore dirigé la lunette catadioptrique à l'endroit on se devait faire cette émersion j'ai commencé à voir Aldebaran sorti de dessous la lune à 6^h 6^m 1^s de la pendule A et je crois que ce temps est le premier moment de son émersion n'ayant rien vû peu de seconds auparavant au même endroit.

"Cette occultation, suivant mon observation est donc arrivée:—

	L'immersion.		L'émersion.	
	Pendules.	Temps vrai.	Pendules.	Temps vrai.
A	$4^h\ 50^m\ 58^s$	$3^h\ 0^m\ 32^s$	$6^h\ 6^m\ 1^s$	$4^h\ 15^m\ 23^s$
M	4 47 $6\frac{1}{2}$	3 0 36	6 2 $6\frac{1}{4}$	4 15 26"

The data for clock-error are somewhat irregular.

We have:—

16 octobre	Sun on meridian (gnomon)	A	$1^h\ 19^m\ 20^s$	M	$1^h\ 18^m\ 55^s$
	Transit of sun over 5th wire of mural sext.		1 19 $27\frac{3}{4}$		

Passage of diameter $2^m\ 10\frac{1}{2}^s$

Pendule A ensuite arrétée, et la pendule M avancée 7 min.

Afterward, the following transits over 5th wire of the mural quadrant:—

Oct 18.	Sun's II limb	A	$1^h\ 34^m\ 41\frac{2}{3}^s$	$M = A - 1^m\ 15\frac{1}{2}^s$
20.	γ Aquilae		7 32 44	
	α Aquilae		7 36 59	
	β Aquilae		7 41 $28\frac{1}{2}$	
22.	Mars		1 1 $51\frac{1}{4}$	
	μ ♓		1 15 $20\frac{1}{4}$	
	Bor. Caud. Ceti . . .		1 37 51	
	Lucida ♈		1 50 50	
	1^a Hyad.		4 3 $30\frac{1}{4}$	
	☾ bord suivant . . .		4 18 $34\frac{1}{2}$	
	Aldebaran		4 19 $28\frac{1}{2}$	
	Rigel		5 1 $11\frac{1}{2}$	$-3^m\ 52^s$ at $4^h\ 54^m$ A
	Bellatrix		5 9 54	
			5 17 38	
	Balt. Orion.		21 58	
			26 $36\frac{1}{2}$	
		At	6 13	$M - A = -3^m\ 55\frac{2}{3}^s$
23.	Sun II limb		1 53 5	−4 9

(Here Delisle "supposes error of meridian" $+10\frac{1}{2}$ seconds.)

	β Aquilæ		7 41 $11\frac{3}{4}$	
	Jupiter		8 42 52	
	Nodi ♓		0 53 25	
	Mars		1 0 $26\frac{1}{2}$	

La pendule M à éte arrétée. Pendule A, Oct. 30, ret. 14^s en la remontant.

Nov. 4.	Sun's centre (mean of limbs) . .	A	2 38 $44\frac{1}{4}$
	Gnomon		2 38 30
	Diff.		$+11\frac{1}{4}$ (sic)

The correction to the time of transit over the mural sextant for the declination of the sun at this time seems to be about $+3^s$. We have then the following results for correction of clock A:—

1736, October 18	Transit of ☉	$-1^h\ 48^m\ 25^s.5$
22.	Transit of Rigel	$-2^h\ 6^m\ 7^s.2$
23.	Transit of ☉	$-2^h\ 7^m\ 34^s.5$.

Interpolating to the time of occultation of Aldebaran, we have:—

Clock-times	$16^h\ 50^m\ 58^s$	$18^h\ 6^m\ 1^s$.
Cock-corrections	$-\ 2^h\ 6^m\ 5^s.6$	$-\ 2^h\ 6^m\ 17^s.6$
Mean times	$14^h\ 44^m\ 52^s.4$	$15^h\ 59^m\ 43^s.4$.

These results are 10^s less than those of Delisle, and more uncertain than usual.

For error of meridian (gnomon), April 22, 1737.

Transit of sun over 5th wire, mural sextant	A	$1^h\ 57^m\ 46\frac{5}{8}^s$	C = A +	$8^m\ 30\frac{1}{4}^s$
Meridian (gnomon)		$58\ \ 14\frac{1}{4}$		$2^h\ 6\ \ 44\frac{1}{2}$ = C
Correction of sextant		$27\frac{5}{8}$		

From 13 pairs equal altitudes with clock H, at a mean interval of $5^h\ 42^m$.

Sun at greatest height	$14^h\ 7^m\ 37.2^s$	H
Euler's correction	$-\ 22.1$	
True transit of sun	$14\ \ 7\ \ 15.1$	
C — H	$-\ 21.7$	
True transit per C	$14\ \ 6\ \ 53.4$	
Observed with gnomon	$14\ \ 6\ \ 44.4$	
Correction of gnomon	$+\ 9.0$	
Correction of sextant	36.6	

1737, May 1.

Transit of sun, mural sextant	A	$2^h\ 33^m\ 4\frac{3}{4}^s$	C = A +	$1^m\ 1\frac{1}{4}^s$
Meridian, gnomon		$2\ \ 33\ \ 35\frac{1}{2}$		$2^h\ 34\ \ 36\frac{3}{4}$ = C
G. — S.		$+\ 30\frac{1}{2}$		

From 12 equal altitudes of the sun, interval $6^h\ 56^m$.

Mean for meridian	$14^h\ 38^m\ 23.8^s$	H
Diff. of clocks C and H	$12\ \ 3\ \ 19.3$	
Apparent noon per C	$2\ \ 35\ \ 4.5$	
Euler's correction	$-\ 20.7$	
Corrected apparent noon	$2\ \ 34\ \ 43.8$	
Error of gnomon	$+\ 7.0$	
Error of sextant	$+\ 37.5$	

1737, May 7, soir.

Immersion of ξ Leonis (pied boreal) instantaneous	N	$0^h\ 57^m\ 27^s$
For clock-correction:		
Sun on meridian (gnomon) May 7	C	$2^h\ 58^m\ 2^s.3$
Mural sextant	A	$2^h\ 53^m\ 48.1^s$
Correct. (G. — S.)		$+32.2^s$

Times of gnomonic noon by the various clocks.

A	$2^h\ 54^m\ 21.3^s$	After which C was retarded 14^s by winding.
C	$2\ \ 58\ \ 2.3$	
M	$2\ \ 51\ \ 5.3$	
H	$14\ \ 43\ \ 51.3$	
N	$3\ \ 10\ \ 24.3$	

The immersion was at—

	Clocks.	True times.
A	$0^h\ 41^m\ 5^s$	$9^h\ 45^m\ 15\frac{3}{4}^s$
C	$0\ \ 44\ \ 45$	$9\ \ 45\ \ 14$
M	$0\ \ 37\ \ 47$	$9\ \ 45\ \ 17\frac{3}{4}$
H	$0\ \ 30\ \ 25$	$9\ \ 45\ \ 15\frac{1}{4}$
N	$0\ \ 57\ \ 27$	$9\ \ 45\ \ 18\frac{3}{4}$

Transmits with mural sextant.

May 7.	Sirius	A	6^h	30^m	50^s
	Procyon		7	22	17
	☽ I		9	5	34
	Cor. ♌		9	50	$52\frac{1}{2}$
	Cauda ♌		11	32	5
	Spica		1	8	$28\frac{1}{2}$
	Arcturus		1	59	58

Pendule H deranged 2 or 3 seconds by the cords.

		A	6^h	25^m	0^s	
		C	6	28	32	
		M	6	21	$43\frac{1}{2}$	
May 8.	Sun on gnomon	A	2	57	49.7	
		C	3	1	46.2	The sextant $33^s.5$ sooner.
		M	2	54	24.7	
		H	14	47	3.7	
		N	3	14	40.2	

Applying $+ 8^s.5$ for correction of gnomon, and taking from clock C on May 7 the 14^s by which it was retarded in winding, we have the following results for clock-correction :—

At transit of ☉.

	May 7.	May 8.
Clock A	$-\ 2^h\ 58^m\ 17^s.9$	$-\ 3^h\ 1^m\ 50^s.4$
C	$-\ 3^h\ 1^m\ 44^s.9$	$-\ 3^h\ 5^m\ 46^s.9$
M	$-\ 2^h\ 55^m\ 1^s.9$	$-\ 2^h\ 58^m\ 25^s.4$
H	$-14^h\ 47^m\ 47^s.9$	$-14^h\ 51^m\ 4^s.4$
N	$-\ 3^h\ 14^m\ 20^s.9$	$-\ 3^h\ 18^m\ 40^s.9.$

The mean time of the occultation, as given by the several clocks, is then as follows :—

A	$9^h\ 41^m\ 21^s.4$
C	$19^s.1$
M	$22^s.4$
H	$17^s.3$:
N	$20^s.4$
Mean	$9^h\ 41^m\ 20^s.8$

1737, May 20.

Ten corresponding pairs of sun's altitudes give for the correction of the gnomon $+ 11^s.5$.

May 23, a. m. Occultation of Jupiter in daylight.

$19^h\ 58^m\ 25\frac{1}{2}^s$ H Jupiter me paraissait toucher le bord éclairé de la lune.

				True times.			
20	0	$15\frac{1}{2}$	H	16^h	1^m	$9\frac{1}{4}^s$	Jupiter me paraisse tout entré.
8	2	$19\frac{1}{4}$	A	16	1	$9\frac{1}{2}$	
8	3	$22\frac{1}{4}$	C	16	1	9	
7	59	$38\frac{1}{4}$	N	[16	0	$58\frac{1}{4}$]	
8	3	$52\frac{1}{2}$	M	16	1	$8\frac{3}{4}$	

Clocks.

May 22.	Sun on gnomon	A	3^h	58^m	20.5^s	
		C	3	59	15.0	(obs.)
		H	3	56	37.5	
		M	3	55	43.8	
	Mural sextant	A	3	57	41.0	
	G. — S.				39.5	
May 23.	Mural sextant	A	4^h	1^m	36.5^s	
		C	4	2	42.8	C
		M	4	3	41.0	
		H	3	59	22.5	
		N	3	58	52.5	

Le fil de la méridienne étant rompu l'on n'a pu observer le passage de l'image du soleil à cette méridienne.

Transits with Mural sextant.

May 22.	Venus	6^h	2^m	22^s	A	A	1^h	54^m	0^s
	Spica	1	13	32		C	1	55	$0\frac{1}{4}$
	Arcturus	2	5	1		M	1	55	9

DELISLE's reduction is correct for clock H. Taking the mean of his results, the apparent and mean times of contact of limbs of Jupiter and the moon will be:—

First contact, apparent time $15^h\ 59^m\ 19^s.1$ (eq. $= -3^m\ 47^s.3$) m. t. $= 15^h\ 55^m\ 31^s.8$

Second contact, apparent time $16^h\ 1^m\ 9^s.1$ . . . . $15^h\ 57^m\ 21^s.8$

Whence local mean time for centre of Jupiter . . . . $15^h\ 56^m\ 26^s.8$

1737, July 23, a. m. Occultation of θ Tauri.

					Obs. HEINSIUS.				DELISLE finds:		
Immersion of star a (meriodionale) (prec.)	A	9^h	5^m	$38\frac{1}{2}^s$	H (1)	21^h	5^m	24^s	12^h	59^m	$36^s.0$
Emersion of b northernmost, and	A	9	38	8	H	21	37	53	13	30	0.2
a	A	9	50	46	H	21	50	31	13	42	36.6

For clocks.

July 21.	Sun culm. mean of 10 pair corresp. altitudes	8^h	2^m	28.7^s	H	Interval $8^h\ 0^m$.
	Euler's correction			+13.8		
	True app. noon	8	2	42.5		
	Clocks B — H		9	22.0		
	True noon B	7	53	20.5		
	Sun on gnomon, meridian	7	53	12.0	B	
	Correction of gnomon			+8.5		
	Transit over 5th wire of mural sextant					$8^h\ 1^m\ 33\frac{1}{2}^s$ A
	Correction (G. — S.)					+42.5
July 23.	Sun on gnomon	7^h	43^m	$50\frac{1}{2}^s$	A or B (?) he says	A
	Sextant	8	9	4	A =	$7^h\ 43^m\ 9^s$ B
July 25.	10 pair equal altitudes, interval $7^h\ 59^m$ give	8^h	15^m	$44^s.7$	H	
	Euler's correction			15.5		
	App. noon	8	16	0.2		
	Diff. clocks, B — H	0	41	18.8		
	App. noon clock B	7	34	41.4	B	
	Meridian (gnomon) B	7	34	34.2		
	Correction of gnomon			+7.2		

Clock-comparisons.

July 21, noon.	22 soir.	22 soir.	23 a. m.	23 noon.
h m s	h m s	h m s	h m s	h m s
8 5 0 A	2 7 0 A	7 50 0 A	9 53 0 A	8 13 0 A
7 55 56 B	1 47 25½ B	19 49 47¾ H	21 52 46 H	7 47 5 B
8 6 53½ C	2 10 46 C	7 50 11 N	9 53 10½ N	8 17 38 C
[0 3 45¼ D]	6 0 56 D	7 52 0 A	9 56 0 A	0 4 48¾ D
11 49 31 E	5 30 54½ E	7 30 22½ B	9 39 39 B	11 24 30 E
8 3 30 G	2 3 57¼ G	7 56 7½ C	[10 0 15½ C]*	8 14 0 A
8 5 18 H	. . .	7 54 0 A	9 56 54 M	8 10 2 G
8 4 53 M	2 7 41⅓ M	11 47 15½ D	9 58 0 A	8 14 27⅛ J
8 5 25 N		11 13 57 E	1 51 1 D	8 20 59¾ K
		7 54 51 M	1 16 31½ E	8 15 4 M
		7 56 0 A	9 59 0 A	8 16 0 A
		7 52 40 G	9 59 13 J	8 15 55 H
		7 56 10 J	9 55 33¼ G	8 16 8 N
		11 56 31¼ K		

* Afterward retarded 13^s in winding.

The clock-corrections have to be interpolated from the noons of July 21 and July 23. The system of proceeding will be this:—Taking clock A as a standard, we shall find the errors of the other clocks for the comparisons nearest the occultations, on the supposition that A is correct. The mean deviation being supposed to arise from changes in the rate of A, the latter will be corrected, so that the result shall be that given by the mean of all the clocks. We have, first:—

Clock.	Other Clocks, *minus* A, etc.		July 22.5, 7^h 52^m A.			9^h 56^m A.		
	(1)	(2)						
	July 21.0, 8^h 5^m A	July 23.0, 8^h 14^m A	Comp.	Obs.	Δ	Comp.	Obs.	Δ
	m s	m s	m s	s	s	m s	s	s
B	− 9 4.0	− 25 55.3	− 21 35.3	− 37.5	− 2.2	− 22 18.7	− 21.0	− 2.3
C	+ 1 53.5	+ 4 38.0	+ 3 55.8	+ (67.5)	+ 2.2	+ 4 2.8	+ 15.5	+ 2.7
E	+ 224 31.0	+ 191 30.0	. .	. .	. .	. .	. .	. .
G	− 1 30.0	− 3 58.0	− 3 20.2	− 20.0	+ 0.2	− 3 26.3	− 26.8	− 0.5
H	+ 0 18.0	− 0 5.0	+ 0 0.9	− 12.2	− 13.1	− 0.1	− 14.0	− 13.9
M	− 0 7.0	+ 1 4.0	+ 0 45.7	+ 51.0	+ 6.3	+ 48.8	+ 54.0	+ 5.2
N	+ 0 25.0	+ 0 8.0	+ 0 12.4	+ 11.0	− 1.4	+ 11.6	+ 10.5	− 1.1

The 13 seconds by which C was thrown back is allowed for in columns Δ. The discordance of H seems to indicate that there is a mistake in its comparison for July 23.0. The general result is that the rate of A agrees very nearly with the mean of the other rates, while the discordance of H and M are such that it is impossible to say whether the correction to the position of A for July 22.5 should be positive or nega-

tive. We shall therefore suppose the rate of A correct; its corrections will be found as follows:—

	July 21.	July 23.
Clock times of ☉'s transit (true mer.) .	$8^h\ 2^m\ 24^s.5$	$8^h\ 9^m\ 53^s.3$
Mean times	$0^h\ 5^m\ 49^s.3$	$0^h\ 5^m\ 55^s.4$
Clock-corrections	$+4^h\ 3^m\ 24^s.8$	$3^h\ 56^m\ 2^s.1$

At the time of the occultation, the difference of clocks A and H was $13^s.3$. It appears, therefore, that HEINSIUS observed the occultations about $1^s.5$ earlier than DELISLE. Taking the mean of the two observers, we have:—

	θ_1 Imm.	θ_1 Em.	θ_2 Em.
Clock-times by A	$9^h\ 5^m\ 37^s.9$	$9^h\ 38^m\ 7^s.2$	$9^h\ 50^m\ 45^s.2$
Clock-corrections	$3^h\ 57^m\ 44^s.0$	$3^h\ 57^m\ 38^s.9$	$3^h\ 57^m\ 37^s.1$
Mean times . .	$13^h\ 3^m\ 21^s.9$	$13^h\ 35^m\ 46^s.1$	$13^h\ 48^m\ 22^s.3$

1738. Jan. 2. Occultation of Aldebaran and the Hyades.

Immersion of *f*, instantaneous. 2 observers diff. $1\frac{1}{2}^s$.				Sec. of app. time.	θ^1 Tauri.			θ^2 Tauri.
1^h	7^m	19^s	A	18	2^h	17^m	$4\frac{3}{4}^s$	52
1	11	45	B	$19\frac{1}{4}$	2	21	$30\frac{1}{2}$	52
6	26	2	D	18	7	35	$34\frac{1}{2}$	$51\frac{1}{2}$
1	9	$47\frac{1}{2}$	G	$18\frac{1}{2}$	2	19	$32\frac{1}{2}$	$51\frac{1}{2}$
1	7	7	H	20	2	17	$4\frac{1}{2}$	54
1	10	28.5	J	18	2	20	$13\frac{1}{2}$	52
1	3	16	K	$18\frac{1}{2}$	2	12	$59\frac{1}{2}$	51
						$+\ 1^s$		

The following are the apparent times from the mean of all the clocks, supposing DELISLE to have applied the right clock-correction:—

Immersion of *f*	6^h	15^m	$18.^s5$		
θ^1	7	24	52.0	-1^s	
θ^2	7	28	8.0	-1^s	
Aldebaran	12	18	46.0	-0.5^s	Emers. $12^h\ 58^m\ 25^s$. Observer thinks right; but the other observer is put down 10^s later.
m	8	46	16		

1737. Nov. 25.

Transit of sun, sextant	4^h	7^m	$43^s.1$	B
gnomon	4	7	34 .5	B
G. — S.			— 8 .6	

1738. Jan. 3.

Transit of sun, sextant	7^h	0^m	$7^s.6$	B
gnomon	6	59	59 .9	B
G. — S.			—7 .7	

Febr. 25.	Correction of gnomon from 6 pair altitudes . .	$+2^s.7$	
March 19.	" " " " . .	+6 .8	
Jan. 2, a. m.	Transits with sextant.		
	Spica	$1^h.\ 14^m\ 37^s$	B
	Arcturus	2 6 $5\frac{1}{2}$	
p. m.	Algenib.	0 2 $31\frac{1}{2}$	
	Luc. ♈	1 55 3	
	1^a Hyadum	4 7 42	
	Aldebaran	4 23 41	
	Sirius	6 37 13	

We have to adopt DELISLE's apparent times. The error of the gnomon is quite uncertain, so that the times are also uncertain. Applying the equation of time, which ranges from $+4^m\ 45^s.5$ to $+4^m\ 52^s.0$, we have for the mean times of the phenomena:—

71 Tauri, immersion, 1738, January 2	$6^h\ 20^m\ 4^s.0$
θ_1	$7^h\ 29^m\ 38^s.5$
θ_2	$7^h\ 32^m\ 54^s.5$
* m, B. A. C. 1391 (?)	$8^h\ 51^m\ 3^s.5$
α Tauri	$12^h\ 23^m\ 37^s.8$
Em	$13^h\ 3^m\ 17^s.8$

1738. Febr. 2, soir.

Immersion of f II at	$17^h\ 5^m\ 37^s$	H	
	4 59 18	A	$7^h\ 55^m\ 34^s$ app. t.
Apparent time, mean of four clocks . . .	$7^h\ 55^m\ 33^s\ 1$		

But the gnomon is supposed correct.

Sun on gnomon Febr. 2	$9^h\ 2^m\ 27^s$	A
" 3	9 6 30	A

1738, Aug. 3. Correction of gnomon . . . . $+7^s.3$
" 19. " " . . . . $+5\ .6$

1738, Octb. 2, soir, occultation d'Aldebaran.
Immersion, exact at . . . . $0^h\ 10^m\ 1.5^s$ H. (2 observers.)
Emersion . . . . 1 10 27 H. Observer HEINSIUS.

1739, Octb. 24, matin, occultation de l'étoile 1 de la sixième grandeur que Mr. FLAMSTEED appele la boréale des trois qui suivent le bras droit des Jumeaux.
Immersion dans la partie éclairé de la lune à . . . . $3^h\ 50^m\ 44^s$ B
Presqu'à la précision d'une seconde.
Moment précise de l'émersion . . . . $5^h\ 1^m\ 37^s$ B

1739, Octbr. 25, matin. Immersion δ Cancri (within 1 sec.) $3^h\ 24^m\ 58^s$ B
Emersion, instantaneous . . . 4 31 32 B

1741, March 24. À midi l'on a commencé à observer aujourdhui le passage du soleil à une nouvelle méridienne filaire tracée dans le grand observatoire supérieure, pendule K comme il suit . . . . $0^h\ 12^m\ 40\frac{1}{4}^s$ Mean of 2.
$0\ 14\ 59\frac{3}{4}$
$2\ 19.5$
The usual gnomon $1\frac{1}{2}$ sec. earlier . . . 0 13 50.0

March 25, soir, immersion η Cancri $0^h\ 7^m\ 54^s$ K (2 observers agree exactly).

1741, March 1. Cor. to meridian (gnomon) per double altitudes . . . . $+\ 1\frac{3}{4}^s$
April 25 . . . . $+\ 6\frac{1}{4}$
Mérid. supérieure . . . . $+\ 1.3$
July 11. Inf. . . . . $+11.0$
Sup. . . . . $+\ 3.9$

Applying $+7^s.0$ for correction of gnomon, we find the correction of clock G on mean time to be:—

August 8.	At $8^h\ 55^m\ 21^s.7$ of G,	corr. $= +3^h\ 9^m\ 49^s.6$
9.	At $8^h\ 58^m\ 40^s.2$ of G,	corr. $= +3^h\ 6^m\ 23^s.4$

The clocks appear to agree so well that no reduction of the others is necessary.

There is, however, an obvious mistake of 4^s in the time of immersion of Aldebaran, as given by G. Interpolating clock-correction, we have the following local mean times:—

1738, August 8.	Immersion of 71 Tauri	$15^h\ 3^m\ 10^s.0$
	Emersion of 71 Tauri	$15^h\ 59^m\ 5^s.9$
	Immersion of θ_1 Tauri	$16^h\ 21^m\ 50^s.7$
	Immersion of θ_2 Tauri	$16^h\ 22^m\ 7^s.7$
	α Tauri	$21^h\ 18^m\ 5^s.4$
	Immersion of α Tauri	$22^h\ 7^m\ 49^s.3$.

§ 11.

POSITIONS OF THE MOON FROM HANSEN'S TABLES, USED IN COMPARING THE PRECEDING OBSERVATIONS WITH THEORY.

When a number of places of the moon are to be computed, several modifications may be made in the use of the tables, whereby the labor of computation will be diminished.

(1) *Omission of terms unimportant on account of their minuteness.*

The older observations are so far from exact that there is no advantage in carrying the computation of the Fundamental Argument to the last degree of precision. Portions of the double-entry tables may, therefore, be omitted in comparing such observations with theory. The minuter terms are those contained in the twenty-seven tables of double-entry: all or a part of these tables may be omitted with the following results:—

If the twenty-seven double-entry tables, XII to XXXVIII, are all omitted, and the sum of their constants, 0.0022240, substituted, the probable deviation of the computed longitude from that given by a rigorous computation will be $\pm 13''.6$

If the seventeen tables, XXII to XXXVIII, are omitted, and the sum of their constants, 4290, substituted, the probable deviation will be $\pm 2''.7$.

If the nine tables, XXX to XXXVIII, are omitted, and the constant, 1140, substituted, the probable deviation of the result will be $\pm 0''.85$.*

(2) *Modifications when many places of the moon are to be computed.*

These modifications refer principally to the formation of the arguments, and the introduction of the terms of long period. They are applicable when places of the moon are required for a series of dates in which there is no interval greatly exceeding a year. The following is a description of the method of forming the arguments actually adopted for the years after 1632.

The dates were divided into groups of not more than ten or twelve, except in cases where a number of dates were crowded together, when the number might be a little greater. A group always had to terminate when an interval of much more than one year was encountered. When no such interval occurred for several successive

* It is to be remarked that in cases where an approximate position of the moon is required for any purpose, this plan of using HANSEN'S Tables, with the omission of the smaller terms (always taking care to include the constant terms of the omitted tables), is much better than that of using the older tables, the elements of which are affected with unknown systematic errors.

groups, the same date was taken as the last of one group and the first of the group following.

All the arguments were then computed for the limiting dates of each group in the usual way. Those of single entry, including g for the intermediate dates, were then found by adding to those for each date the interval in days between that and the date next following, and subtracting the greatest number of entire periods contained in the sum. The double-entry arguments are constant for each period of g, and change by a definite amount for every new period. To pass from those for one date to those for the date next following, it was only necessary to add or subtract a number depending on the number of periods of g which had terminated during the interval. To enable this to be done with the least labor, and risk of error, a long slip of paper was prepared for each number of periods of g. On the bottom of each slip was written, in regular order, the quantity by which each argument increased during the number of periods corresponding to the slip. On the opposite side and edge of the slip were written, in red ink, the complements of these numbers; that is, the quantities by which they fell short of one period of the argument. Then, to pass from the values of the arguments from one date to those for the succeeding one, the number of entire periods of g which had been subtracted was noted, and the corresponding slip taken. Being laid over the row of arguments, the red numbers were first subtracted in all cases where they were less than the argument. Then, turning the slip over, the black numbers were added in all the remaining cases.

When the end of the group was reached, the series of arguments thus obtained was compared with those derived by direct computation; and if they agreed, which was nearly always the case, the intermediate arguments were all considered correct. The only way in which they could be erroneous would be by two opposite and equal errors entering into the same series. The computer who formed the arguments in this way was the Rev. PARKER PHILLIPS, whose conscientiousness and accuracy were such as to inspire entire confidence in his work.

(3) *Terms of long period produced by Venus.*

The variation of these terms is so slow and regular that it is much easier to include their sum in the original computations of the arguments than to compute and add them for each date. Their sum was, therefore, computed for the beginning of every tenth year, and interpolated to every year, as shown in the next table. Their product by the proper factors to form the corrections to Arguments 32 and 33 was also computed, and included in the same table. These arguments are farther to be corrected on account of the terms of long period corresponding to Arguments 28 and 29; but the error from omitting these terms is so small, scarcely $0''.1$ in the mean, that they have been neglected. In place of them, the constant quantities $+200$ and $+186$ have been included in the table.

The addition of these corrections to the three leading arguments necessitates a correction corresponding to their change during the interval between two consecutive dates, to be applied to that interval in order to find the total change of the argument. The amount of this change for 100 days in units of the last place in the argument is tabulated, and shown in the table next following that last described.

The explanation of the several parts of the table is as follows:—

Column Δg gives, for the beginning of each year, the sum of HANSEN'S Venus-terms of long period, as derived from Tables XLI and XLII, Arguments 30 and 31, without any modification.

The precepts of the tables direct that Arguments 32 and 33 be corrected by the sum of the four Tables XXXIX to XLII inclusive, multiplied by the factors 0.11545 and 0.10717 respectively. The sum of the first two tables differs so little from that of their constants, 1735, that we may use the latter; we have therefore put

$$\Delta\ 32 = 0.11545\ (\Delta g + 1735) = 0.11545\ \Delta g + 200$$
$$\Delta\ 33 = 0.10717\ (\Delta g + 1735) = 0.10717\ \Delta g + 186.$$

Arguments 32 and 33 are to be corrected by these quantities respectively.

The change of g between two consecutive dates varies, not only in consequence of the variation of Δg, but of the secular acceleration. The change of the variation in the seventh decimal place of g for 100 days, in order to reduce it to the adopted period corresponding to the epoch 1800, as arising from both these sources, is as follows:—

Date.	Secular Term.	Venus Terms.	Date.	Secular Term.	Venus Terms.
1620	−103.31	− 4.11	1710	− 51.72	+ 30.62
1630	− 97.58	+ 4.06	1720	− 45.98	+ 24.85
1640	− 91.85	+ 12.23	1730	− 40.24	+ 17.11
1650	− 86.12	+ 19.93	1740	− 34.49	+ 8.04
1660	− 80.39	+ 26.50	1750	− 28.74	− 1.74
1670	− 74.66	+ 31.61	1760	− 22.99	− 11.64
1680	− 68.93	+ 34.79	1770	− 17.25	− 21.10
1690	− 63.19	+ 35.70	1780	− 11.50	− 29.46
1700	− 57.46	+ 34.30	1790	− 5.75	− 36.09
1710	− 51.72	+ 30.62	1800	0.00	− 40.50

The sum of these terms, interpolated to the beginning of each year, is given in the table as $\frac{d\,\Delta g}{dt}$, while the corresponding terms for correcting Arguments 32 and 33 follow. To find the change of g and of Arguments 32 and 33 between the epochs t and $t + \Delta t$, it is necessary to take out the values of these three derivatives for the time $t + \frac{1}{2}\Delta t$, when we shall have:—

$$\text{Change of Arg.} = \Delta t + \frac{\Delta t}{100} \cdot \frac{d\,\Delta\,\text{Arg.}}{dt} - i \times \text{Period};$$

it being remarked that the second term is given in units of the last place of decimals.

Date.	Δg	Diff.	Δ 32	Δ 33	$\frac{d\Delta g}{dt}$	$\frac{d\Delta 32}{dt}$	$\frac{d\Delta 33}{dt}$
1630	3289	15	580	539	. . .	. . .	. . .
31	3304	18	581	540	. . .	. . .	. . .
32	3322	21	583	542	. . .	. . .	. . .
33	3343	25	585	544	. . .	. . .	. . .
34	3368	28	588	547	. . .	. . .	. . .
35	3396	32	591	550	. . .	. . .	. . .
36	3428	36	595	554	. . .	. . .	. . .
37	3464	39	600	557	. . .	. . .	. . .
38	3503	42	604	562	. . .	. . .	. . .
39	3545	45	609	566	. . .	. . .	. . .
1640	3590	47	614	571	. . .	. . .	. . .
41	3637	49	619	576	. . .	. . .	. . .
42	3686	52	624	582	. . .	. . .	. . .
43	3738	55	630	587	. . .	. . .	. . .
44	3793	58	637	593	. . .	. . .	. . .
45	3851	61	644	599	. . .	. . .	. . .
46	3912	63	651	606	. . .	. . .	. . .
47	3975	66	658	613	. . .	. . .	. . .
48	4041	69	666	620	. . .	. . .	. . .
49	4110	72	674	627	. . .	. . .	. . .
1650	4182	75	683	635	. . .	. . .	. . .
51	4257	78	691	643	. . .	. . .	. . .
52	4335	81	700	651	. . .	. . .	. . .
53	4416	84	709	659	. . .	. . .	. . .
54	4500	86	719	668	. . .	. . .	. . .
55	4586	88	729	677	. . .	. . .	. . .
56	4674	89	740	687	. . .	. . .	. . .
57	4763	91	750	696	. . .	. . .	. . .
58	4854	93	761	706	. . .	. . .	. . .
59	4947	96	772	716	. . .	. . .	. . .
1660	5043	98	782	726	. . .	. . .	. . .
61	5141	100	793	737	. . .	. . .	. . .
62	5241	102	805	748	. . .	. . .	. . .
63	5343	104	817	758	. . .	. . .	. . .
64	5447	107	829	769	. . .	. . .	. . .
65	5554	109	841	780	. . .	. . .	. . .
66	5663	111	854	792	. . .	. . .	. . .
67	5774	113	866	805	. . .	. . .	. . .
68	5887	115	879	817	. . .	. . .	. . .
69	6002	117	892	830	. . .	. . .	. . .
1670	6119	118	905	842	. . .	. . .	. . .
71	6237	119	918	855	. . .	. . .	. . .
72	6356	120	932	867	. . .	. . .	. . .
73	6476	122	947	880	. . .	. . .	. . .
74	6598	123	961	893	. . .	. . .	. . .
75	6721	124	975	907	. . .	. . .	. . .
76	6845	125	990	920	. . .	. . .	. . .
77	6970	126	1004	933	− 36.5	+ 8.1	+ 1.8
78	7096	127	1019	947	35.7	8.1	1.8
1679	7223	128	1033	960	− 34.9	+ 8.1	+ 1.9

Date.	Δ g	Diff.	Δ 32	Δ 33	$\frac{d\Delta g}{dt}$	$\frac{d\Delta 32}{dt}$	$\frac{d\Delta 33}{dt}$
1680	7351	129	1049	973	− 34.1	+ 8.1	+ 1.9
81	7480	129	1064	987	33.4	8.1	1.9
82	7609	130	1079	1001	32.6	8.1	2.0
83	7739	130	1094	1015	31.9	8.1	2.0
84	7869	131	1109	1029	31.2	8.1	2.0
85	8000	131	1124	1043	30.5	8.0	2.0
86	8131	131	1139	1057	29.9	8.0	2.0
87	8262	132	1154	1071	29.3	7.9	2.0
88	8394	132	1169	1085	28.7	7.9	2.1
89	8526	132	1185	1099	28.1	7.8	2.1
1690	8658	131	1200	1113	− 27.5	+ 7.8	+ 2.1
91	8789	131	1215	1127	. .	. .	. .
92	8920	131	1230	1142	. .	. .	. .
93	9051	131	1245	1156	. .	. .	. .
94	9182	130	1260	1170	. .	. .	. .
95	9312	130	1275	1184	. .	. .	. .
96	9442	129	1290	1198	. .	. .	. .
97	9571	129	1305	1212	. .	. .	. .
98	9700	128	1320	1226	. .	. .	. .
1699	9828	128	1335	1240	. .	. .	. .
1700	9956	127	1349	1254	− 23.2	+ 7.3	+ 2.1
01	10083	126	1364	1268	22.8	7.3	2.1
02	10209	124	1378	1281	22.5	7.2	2.1
03	10333	123	1393	1295	22.2	7.2	2.0
04	10456	122	1407	1308	22.0	7.1	2.0
05	10578	120	1421	1321	21.8	7.0	2.0
06	10698	118	1435	1334	21.6	6.9	2.0
07	10816	117	1449	1346	21.4	6.9	1.9
08	10933	115	1462	1358	21.3	6.8	1.9
09	11048	113	1475	1370	21.2	6.7	1.9
1710	11161	113	1488	1382	21.1	6.6	1.9
11	11274	112	1500	1394	21.1	6.5	1.9
12	11386	109	1513	1406	21.1	6.4	1.8
13	11495	107	1526	1417	21.0	6.3	1.8
14	11602	105	1538	1428	21.0	6.2	1.7
15	11707	102	1551	1439	21.0	6.1	1.7
16	11809	100	1563	1450	21.0	6.0	1.6
17	11909	97	1574	1461	21.0	5.9	1.6
18	12006	95	1585	1471	21.1	5.8	1.5
19	12101	92	1596	1481	21.1	5.7	1.5
1720	12193	89	1607	1491	21.1	5.6	1.4
21	12282	87	1617	1500	21.2	5.5	1.4
22	12369	84	1627	1510	21.3	5.4	1.3
23	12453	82	1637	1519	21.4	5.3	1.3
24	12535	80	1647	1528	21.6	5.2	1.2
25	12615	77	1656	1537	21.8	5.1	1.2
26	12692	75	1665	1545	22.0	5.0	1.1
27	12767	72	1673	1553	22.2	4.8	1.0
28	12839	69	1682	1562	22.5	4.7	1.0
1729	12908	66	1690	1569	− 22.8	+ 4.6	+ 0.9

Date.	Δg	Diff.	Δ 32	Δ 33	$\frac{d\Delta g}{dt}$	$\frac{d\Delta 32}{dt}$	$\frac{d\ 33}{dt}$
1730	12974	61	1697	1576	− 23.1	+ 4.4	+ 0.8
31	13035	58	1705	1583	23.4	4.3	0.8
32	13093	55	1711	1590	23.7	4.2	0.7
33	13148	52	1718	1596	24.0	4.0	0.6
34	13200	49	1724	1601	24.4	3.9	0.5
35	13249	45	1730	1607	24.7	3.7	0.4
36	13294	42	1735	1612	25.0	3.6	0.4
37	13336	38	1740	1616	25.3	3.4	0.3
38	13374	36	1744	1620	25.7	3.3	0.2
39	13410	32	1748	1624	26.0	3.1	+ 0.1
1740	13442	28	1752	1627	26.4	3.0	0.0
41	13470	24	1755	1630	26.8	2.9	− 0.1
42	13494	21	1758	1633	27.2	2.8	0.2
43	13515	17	1760	1635	27.6	2.6	0.3
44	13532	14	1762	1637	28.0	2.5	0.4
45	13546	10	1764	1638	28.4	2.3	0.5
46	13556	7	1765	1640	28.8	2.1	0.6
47	13563	+ 3	1766	1641	29.3	2.0	0.7
48	13566	− 1	1766	1641	29.7	1.8	0.8
49	13565	4	1766	1640	30.1	1.7	0.9
1750	13561	8	1765	1640	30.5	1.5	1.0
51	13553	12	1764	1639	30.9	1.4	1.1
52	13541	15	1762	1638	31.3	1.2	1.2
53	13526	19	1760	1636	31.8	1.1	1.3
54	13507	23	1758	1634	32.2	0.9	1.4
55	13484	26	1756	1631	32.6	0.8	1.5
56	13458	30	1753	1628	33.0	0.6	1.5
57	13428	34	1750	1625	33.4	0.5	1.6
58	13394	37	1746	1621	33.8	0.3	1.7
59	13357	42	1742	1617	34.2	+ 0.2	1.8
1760	13315	45	1737	1612	34.6	0.0	1.9
61	13270	48	1732	1608	35.0	− 0.2	2.0
62	13222	52	1727	1603	35.4	0.3	2.0
63	13170	55	1721	1597	35.8	0.5	2.1
64	13115	59	1715	1591	36.1	0.6	2.2
65	13056	62	1708	1585	36.5	0.8	2.3
66	12994	66	1701	1578	36.9	0.9	2.3
67	12928	69	1693	1571	37.2	1.0	2.4
68	12859	72	1685	1564	37.6	1.1	2.5
69	12787	76	1677	1557	38.0	1.2	2.6
1770	12711	80	1668	1549	38.3	1.4	2.7
71	12631	83	1658	1540	38.6	1.5	2.7
72	12548	86	1649	1531	38.9	1.7	2.8
73	12462	89	1639	1522	39.2	1.9	2.9
74	12373	92	1629	1512	39.5	2.0	3.0
75	12281	95	1618	1502	39.8	2.1	3.0
76	12186	98	1607	1492	40.0	2.3	3.1
77	12088	101	1595	1481	40.3	2.5	3.2
78	11987	104	1584	1471	− 40.6	− 2.7	− 3.3
79	11883	−107	. .	. .	. .	. .	. .
1780	11776		. .	. .	. .	. .	. .

The terms omitted were as follows:—

For all the Arabian observations and for those of PTOLEMY, all the double-entry tables were omitted.

From 1621 to 1666, Tables XXII to XXXVIII of double-entry were omitted.

In all cases of such omission, the sum of the constants included in the tables was added.

From 1671 onward, all the tables were included.

Still another modification consists in the omission of the nutation. Since the comparison of the place of the moon with that of the sun or star was made in longitude, the equinox to which each was referred was indifferent; the mean equinox of the date has therefore been chosen. The nutation terms being given in Tables VII and IX of *Longitude Vrai*, these tables were omitted, andthe sum of the constants, $0^\circ.00550$, substituted.

After the formation of the arguments, the computations of longitude, latitude, and parallax were made in duplicate by two independent computers, and the work was then compared by myself. Where differences of importance were found, the computer who was wrong corrected his work without reference to that of the other. That these precautions have secured absolute freedom from error cannot be asserted. Discrepancies of various sorts, which developed themselves in the final results, led to the discovery of some errors which escaped all the preliminary examination, and which are worthy of mention as affording hints to others. In one instance, an error of 20 days in forming an argument, though marked as wrong, failed to be corrected. About half a group of latitudes (dates 83 to 91) were in error from this cause. In another instance, some inadvertence in attempting to correct an error led to a common error in two computations. In a third instance, a typographical error in the tables led to both computations of longitude being wrong by about $20''$.*

This last source of error is that which I now most fear. Through some oversight, some of the volumes of tables used by the computers did not have the typographical errors corrected. Such errors in the longitude, if important, will admit of detection where two longitudes with the different variations are computed for the same day; and it was by comparing the difference of two longitudes with the variations that the mistake above mentioned was found.

* In my preliminary paper in the *American Journal of Science and Arts* for September, 1870, the occultation of Aldebaran on 1680, November 7, appears as unaccountably discordant. The difficulty arose from a typographical error of $1'$ in the tabular principal term of latitude.

Year.	Date.	Greenwich Mean Time.	Sun's Geocentric—		Moon's Geocentric—			Paral-lax.
			Longitude. Mean Equin.	Semi-diam.	Longitude. Mean Equin.	Motion in $0^d.01$.	Latitude.	
		h m s	° ′ ″	′ ″	° ′ ″	′ ″	° ′ ″	′ ″
− 720	Mar. 19	5 0 0	351 31 30.4	15 57	170 59 20.9	7 34.32	+ 0 3 39	55 44
− 719	Mar. 8	8 0 0	340 41 49.4	16 0	160 30 21.7	7 6.02	+ 0 46 42	53 55
− 719	Sept. 1	3 0 0	150 54 28.0	16 0	329 55 25.4	9 4.97	− 0 37 45	61 10
− 620	April 21	13 0 0	24 23 36.8	15 49	204 16 11.0	7 6.78	+ 0 52 50	54 2
− 522	July 16	8 0 0	106 33 14.6	15 48	286 37 12.1	7 11.10	− 0 40 53	54 14
− 501	Nov. 19	8 0 0	231 54 14.6	16 16	51 46 47.6	7 5.02	+ 0 50 43	53 51
− 490	April 25	7 0 0	28 31 25.9	15 49	207 55 48.9	8 7.91	+ 1 1 36	57 48
− 382	Dec. 22	16 0 0	267 1 57.5	16 17	86 46 52.5	8 42.95	− 0 57 49	59 52
− 381	June 18	4 0 0	80 27 49.9	15 45	259 47 0.2	7 10.34	+ 0 46 28	54 11
− 381	Dec. 12	6 0 0	256 9 56.4	16 17	75 12 47.0	9 8.24	− 0 21 10	61 20
− 200	Sept. 22	5 0 0	176 0 41.3	16 4	356 20 25.1	7 28.60	+ 0 33 22	55 22
− 199	Mar. 19	8 0 0	355 22 22.6	15 58	173 56 22.8	8 16.66	+ 0 4 54	58 19
− 199	Sept. 11	10 0 0	165 1 43.1	16 2	343 55 3.4	8 19.93	+ 0 0 7	58 30
− 173	April 30	10 0 0	35 40 6.5	15 49	214 45 55.5	9 4.43	− 0 35 42	61 5
− 140	Jan. 27	6 0 0	304 31 56.5	16 12	123 26 23.7	9 8.10	+ 0 46 34	61 20
+ 125	April 5	6 0 0	14 16 11.9	15 54	194 2 38.5	8 18.60	+ 0 57 26	58 26
133	May 6	8 0 0	44 11 33.5	15 48	223 56 8.0	7 20.03	− 0 25 40	54 50
134	Oct. 20	8 0 0	206 15 6.2	16 11	25 54 53.2	7 33.38	− 0 26 45	55 40
136	Mar. 5	12 0 0	344 36 35.8	16 2	163 51 50.9	8 53.27	− 0 53 11	60 28
829	Nov. 29	16 36 14	252 37 1.4	16 15	251 37 35.6	7 51.53	+ 0 22 7	56 54
829	Nov. 29	18 26 54	252 41 43.2	16 15	252 38 3.6	7 52.27	+ 0 16 49	56 56
854	Aug. 11	12 1 7	142 35 22.2	15 52	321 40 19.9	8 48.28	+ 0 18 14	60 16
856	June 21	12 21 58	94 10 35.2	15 45	273 34 30.6	8 15.06	− 0 45 12	58 14
923	June 1	6 56 33	74 43 21.5	15 46	255 29 51.2	8 37.30	− 0 43 50	59 34
923	Nov. 10	16 21 8	233 26 48.7	16 14	232 37 16.1	9 4.21	+ 0 32 23	61 16
923	Nov. 10	17 32 32	233 29 49.5	16 14	233 22 23.0	9 4.07	+ 0 28 14	61 11
925	April 11	2 38 36	26 7 56.1	15 54	204 16 46.0	8 25.73	+ 0 36 51	58 57
925	April 11	7 47 49	26 20 32.1	15 54	207 18 22.5	8 27.80	+ 0 20 2	59 6
927	Sept. 13	12 50 46	175 11 58.9	16 0	354 28 43.6	9 5.48	+ 0 51 14	61 17
928	Aug. 17	15 29 29	149 36 57.7	15 53	149 7 31.6	7 51.39	− 0 13 10	56 54
929	Jan. 27	8 5 32	313 14 7.1	16 13	131 48 27.9	8 30.55	+ 0 30 37	59 17
933	Nov. 4	13 17 45	227 48 52.7	16 13	46 54 43.2	7 14.45	− 0 5 53	54 31
977	Dec. 12	18 19 2	267 1 39.0	16 17	265 49 0.2	9 6.65	+ 0 35 14	61 25
977	Dec. 12	20 36 10	267 7 28.7	16 17	267 16 6.2	9 6.38	+ 0 27 16	61 25
978	June 8	0 22 29	81 48 51.6	15 45	81 58 28.1	7 6.24	− 0 6 10	53 57
978	June 8	2 42 13	81 54 24.5	15 45	83 7 17.5	7 5.97	+ 0 0 16	53 58
979	May 14	5 52 0	57 56 59.6	15 48	238 51 9.2	8 18.24	+ 0 32 26	58 31
979	May 28	4 12 58	71 15 6.9	15 46	71 47 32.3	7 36.34	+ 0 39 3	55 55
979	Nov. 6	8 3 40	229 27 8.9	16 13	48 42 43.9	8 18.33	− 0 37 36	58 34
979	Nov. 6	11 18 0	229 35 21.4	16 13	50 34 49.0	8 17.20	− 0 27 15	58 28
980	May 2	14 26 0	47 31 15.6	15 49	228 24 21.3	7 28.20	− 0 12 2	55 26
981	April 21	13 28 0	36 39 56.3	15 52	216 14 56.3	7 5.32	− 0 45 50	53 55
981	Oct. 15	14 7 0	208 1 33.9	16 8	27 24 21.5	9 2.06	+ 0 46 36	61 7
983	Mar. 1	9 55 0	346 13 18.5	16 5	165 18 39.2	8 38.20	+ 0 31 50	59 42
983	Mar. 1	13 40 0	346 22 36.4	16 5	167 33 27.9	8 36.75	+ 0 19 24	59 35
985	July 20	2 56 30	122 17 35.7	15 47	122 43 17.6	8 10.32	+ 0 15 4	58 1
985	July 20	4 18 13	122 20 51.7	15 48	123 29 43.1	8 10.89	+ 0 10 50	58 3
986	Dec. 18	14 53 0	272 49 1.0	16 17	92 16 49.4	7 5.90	+ 0 30 16	53 58
990	April 12	7 42 0	27 34 15.2	15 54	206 43 56.9	7 6.15	− 0 37 29	53 59
990	April 12	11 4 0	27 42 24.7	15 54	208 23 26.7	7 5.94	− 0 28 17	53 59
993	Aug. 19	17 36 5	151 54 39.6	15 53	150 28 33.5	9 2.40	+ 0 5 17	61 4
1002	Mar. 1	9 41 18	346 35 57.9	16 5	165 37 27.9	9 8.07	− 0 12 7	61 27
1004	Jan. 23	1 51 0	308 43 17.5	16 14	296 1 56.8	8 32.44	− 1 2 7	59 20
1004	Jan. 24	1 51 0	309 44 2.2	16 14	310 9 24.9	8 23.57	+ 0 15 51	58 50

No.	Date.	Greenwich Mean Time.		Geocentric Long. of Moon.	Motion in od.oi.	Geocentric Lat. of Moon.	Motion in od.oi.	Parallax.	Motion in od.oi.
		h m s		° ' "	' "	° ' "	"	' "	"
1	1621, May 20	18 39 34	.7774768	59 5 58.7	7 53.11	+ 0 45 26.4	− 43.19	56 58.5	. .
2	" "	21 5 10	.8787879	60 25 46.4	7 54.05	+ 0 38 8.1	− 43.38	57 1.9	. .
3	1623, July 5	9 24 16	.3918519	198 24 43.4	8 18.02	− 0 47 52.7	+ 43.42	58 42.7	. .
4	1627, June 17	10 8 14	.4223843	144 51 53.2	7 51.53	+ 1 25 49.9	+ 40.95	57 5.9	. .
4a	" Sept. 18	10 29 20	.4370371	278 37 23.8	7 19.99	+ 2 26 51.8	− 34.76	55 8.7	. .
5	1630, June 10	4 48 0	.2000000	79 1 13.7	8 5.21	+ 0 32 57.7	+ 44.54	57 42.8	. .
6	" "	7 12 0	.3000000	80 22 11.4	8 6.25	+ 0 40 22.9	+ 44.49	57 46.4	. .
7	1632, Feb. 5	15 0 0	.6250000	136 25 3.0	7 58.98	+ 4 58 21.5	− 4.52	57 6.5	. .
8	1633, Feb. 14	11 20 4	.4722685	46 6 19.3	7 22.22	+ 2 18 28.6	+ 35.28	55 20.4	. .
9	" Apr. 8	4 48 0	.2000000	20 7 46.5	7 53.90	+ 0 12 4.5	+ 43.74	57 1.8	. .
10	1634, Dec. 30	5 43 44	.2387037	54 24 14.8	8 11.76	+ 4 46 35.3	+ 14.18	58 0.3	. .
11	1635, Aug. 26	9 24 22	.3919155	316 31 29.9	8 37.00	− 1 26 4.5	+ 45.97	59 35.6	. .
12	1637, Mar. 29	9 0 0	.3750000	55 14 22.7	8 38.44	+ 4 38 12.3	− 17.99	59 35.6	. .
13	1638, Jan. 24	7 17 49	.3040394	54 34 6.4	8 17.34	+ 4 7 54.9	− 28.45	58 33.6	. .
14	" Dec. 20	16 7 42	.6720139	90 38 16.8	8 32.60	− 0 15 9.0	− 47.36	59 20.0	. .
15	1639, Apr. 7	9 0 21	.3752431	67 33 17.6	7 36.62	+ 1 7 55.4	− 39.45	56 6.9	. .
16	" June 1	3 36 0	.1500000	70 37 53.0	7 50.59	+ 0 43 53.6	− 42.99	56 49.9	. .
17	" "	6 0 0	.2500000	71 56 22.8	7 51.67	+ 0 36 42.3	− 43.19	56 53.4	. .
17a	1641, Apr. 13	8 3 43	.3359143	63 55 47.3	7 5.41	− 1 58 40.0	− 36.37	54 1.8	. .
18	1644, Nov. 14	15 36 0	.6500000	66 15 48.3	9 4.03	− 5 0 36.6	+ 1.70	60 55.8	. .
19	1645, Aug. 21	0 0 0	.0000000	148 42 39.6	8 7.94	+ 0 51 18.0	+ 44.41	57 52.7	. .
20	" "	3 0 0	.1250000	150 24 10.0	8 6.94	+ 1 0 31.5	+ 44.07	57 48.0	. .
21	" Oct. 7	15 0 0	.6250000	51 21 48.1	8 52.87	− 5 4 6.1	+ 3.08	60 20.1	. .
21a	" Oct. 8	12 0 0	.5000000	64 6 43.9	8 49.06	. . .	. .	. .	. .
21½	" "	15 0 0	.6250000	66 6 7.5	8 48.26	− 4 49 3.7	+ 14.86	60 4.2	. .
22	1647, Jan. 20	14 24 0	.6000000	123 56 43.0	9 9.47	+ 1 6 32.9	+ 49.66	61 28.5	. .
23	" Apr. 12	10 0 0	.4166667	119 30 52.4	8 28.18	+ 1 7 14.6	+ 43.68	59 17.0	. .
24	1652, Apr. 7	21 36 0	.9000000	18 36 33.0	8 48.80	+ 0 43 31.2	+ 48.40	60 17.1	. .
25	" Apr. 8	0 0 0	.0000000	20 4 37.0	8 48.08	+ 0 51 24.3	+ 48.11	60 14.1	. .
26	1654, Aug. 11	20 0 0	.8333333	138 21 50.1	8 24.22	+ 0 36 22.6	− 46.22	58 51.1	. .
27	" "	22 24 0	.9333333	139 45 47.6	8 23.28	+ 0 28 40.1	− 46.36	58 47.4	. .
28	1656, Jan. 26	0 30 0	.0208333	306 8 52.3	7 4.33	+ 0 47 56.6	+ 38.83	53 56.3	. .
29	" "	2 54 0	.1208333	307 19 35.1	7 4.30	+ 0 55 24.2	+ 38.66	53 56.1	. .
30	" Mar. 1	7 20 9	.3056597	44 7 19.2	7 44.94	+ 4 54 8.4	− 12.55	56 29.5	. .
31	1658, Oct. 14	9 52 6	.4111806	61 25 33.8	7 4.01	+ 0 8 6.6	− 38.48	54 2.5	. .
32	1660, Apr. 26	13 23 51	.5582292	238 38 39.5	8 21.52	+ 2 8 20.1	+ 42.28	58 40.5	. .
33	" June 17	9 41 39	.4039236	199 0 32.9	7 41.30	− 1 16 33.8	+ 40.01	56 30.8	. .
34a	1661, Mar. 29	21 0 0	.8750000	9 36 33.8	8 59.10	+ 0 37 16.9	− 49.48	60 51.9	. .
34b	" "	23 24 0	.9750000	11 6 20.2	8 58.50	+ 0 29 0.8	− 49.54	60 49.8	. .
34	" Mar. 30	21 0 0	.8750000	24 28 26.1	8 50.64	− 0 45 6.6	− 48.65	60 24.6	. .
35	" "	23 24 0	.9750000	25 56 45.6	8 49.52	− 0 53 30.8	− 48.24	60 20.7	. .
36	" Aug. 3	7 15 0	.3020833	227 8 42.2	7 25.10	+ 3 9 50.3	+ 31.35	55 28.4	. .
37	1663, Mar. 14	8 0 0	.3333333	62 53 20.6	8 37.57	− 5 13 51.0	− 5.63	59 33.8	. .
38	" Aug. 18	8 0 57	.3339931	325 32 18.9	7 41.56	+ 0 28 5.2	− 42.46	56 16.5	. .
39	" "	8 50 52	.3686574	325 58 59.1	7 41.92	+ 0 25 26.0	− 42.57	56 17.7	. .
40	1664, Mar. 31	8 25 0	.3506944	65 40 39.2	8 28.75	− 4 55 29.4	+ 12.18	59 1.5	. .
41	1666, July 1	17 36 0	.7333333	99 13 35.0	7 58.12	+ 0 20 14.2	+ 44.01	57 17.4	. .
42	" "	20 0 0	.8333333	100 33 20.2	7 59.12	+ 0 27 34.9	+ 44.07	57 21.1	. .
43	1671, Mar. 14	7 46 0	.3236111	46 28 53.4	8 45.24	+ 3 35 31.6	+ 35.52	60 7.6	. .

No.	Date.	Greenwich Mean Time.		Geocentric Long. of Moon.	Motion in $0^{d}.01$.	Geocentric Lat. of Moon.	Motion in $0^{d}.01$.	Parallax.	Motion in $0^{d}.01$.
		h m s		° ′ ″	′ ″	° ′ ″	″	′ ″	″
44	1671, Mar. 14	8 37 0	.3590278	46 59 53.3	8 44.81	+ 3 37 37.1	+ 35.24	60 6.3	. .
45	" Apr. 22	9 29 0	.3951389	198 38 41.2	7 5.02	− 1 21 13.2	− 37.49	53 59.5	. .
46	" "	10 39 0	.4437500	199 13 6.3	7 5.02	− 1 24 15.0	− 37.41	53 59.2	. .
47	" May 31	14 21 0	.5979167	348 27 34.7	8 19.36	− 1 6 46.2	+ 43.20	58 47.2	. .
48	1672, May 18	18 24 30	.7670139	320 33 46.2	7 29.06	− 1 50 16.8	+ 36.84	55 46.1	. .
49	" "	20 3 30	.8357639	321 25 5.9	7 29.86	− 1 46 2.1	+ 37.22	55 49.0	. .
50	" Aug. 2	10 18 20	.4293982	246 54 50.5	7 7.97	− 5 13 26.2	+ 0.18	54 10.8	. .
51	" Sept. 25	10 7 36	.4219445	238 50 21.1	7 16.61	− 5 10 27.3	− 4.88	54 41.6	. .
52	" Nov. 5	11 30 0	.4791667	54 52 19.4	8 56.47	+ 4 58 1.2	+ 6.87	60 29.8	. .
53	1673, Mar. 22	7 0 0	.2916667	55 35 37.6	8 18.06	+ 5 10 53.3	+ 0.66	58 23.2	. .
54	1674, Aug. 23	12 36 0	.5250000	54 25 9.4	7 33.17	+ 4 42 45.4	− 17.43	55 51.8	+ 0.45
55	" "	13 48 0	.5750000	55 2 57.5	7 33.71	+ 4 41 20.9	− 17.85	55 54.2	. .
56	1675, Jan. 11	7 0 0	.2916667	111 34 22.0	8 26.16	− 0 6 35.2	− 46.83	58 57.6	. .
57	" "	8 12 0	.3416667	112 16 34.3	8 26.77	− 0 10 29.4	− 46.87	58 59.3	. .
58	" June 22	16 0 0	.6666667	90 46 2.8	7 43.89	+ 0 56 49.6	− 42.09	56 24.7	. .
59	" "	17 12 0	.7166667	91 24 43.2	7 44.26	+ 0 53 18.8	− 42.15	56 26.3	. .
60	1676, Feb. 29	10 22 57	.4326042	169 3 17.1	8 38.29	− 4 56 59.6	− 7.80	59 25.8	. .
61	" "	11 20 3	.4722570	169 37 32.6	8 38.62	− 4 57 31.9	− 7.42	59 26.9	. .
62	" Mar. 18	7 16 28	.3031019	47 50 0.3	7 5.74	+ 3 9 51.1	− 29.00	54 7.0	. .
63	" Mar. 23	13 17 20	.5537038	110 50 36.5	7 32.52	− 2 4 28.3	− 36.37	55 57.5	. .
64	" June 10	20 0 0	.8333333	80 13 23.4	7 8.10	+ 0 13 46.0	− 39.58	54 11.9	. .
65	" "	22 24 0	.9333333	81 24 46.6	7 8.47	+ 0 7 9.5	− 39.62	54 13.1	. .
66	" June 29	11 29 59	.4791551	334 57 26.9	8 0.24	+ 5 1 25.2	+ 13.30	57 25.3	. .
67*a*	" Aug. 19	8 24 0	.3500000	280 17 41.7	8 30.70	+ 1 43 7.6	+ 42.61	59 18.2	. .
67	" "	12 0 0	.5000000	282 25 22.2	8 30.52	+ 1 53 42.1	+ 41.95	59 16.7	+ 0.27
68	" Aug. 31	12 0 0	.5000000	77 16 55.7	7 5.81	+ 0 10 11.4	− 37.71	54 19.3	. .
69	" "	14 24 0	.6000000	78 27 55.5	7 6.02	+ 0 3 54.3	− 37.79	54 20.3	+ 0.08
70	" Sept. 26	17 30 24	.7294444	64 16 57.3	7 5.41	+ 1 3 17.4	− 36.91	54 13.5	. .
71	" Nov. 9	5 40 55	.2367476	281 53 33.0	8 42.36	+ 2 28 36.5	+ 42.34	60 1.3	. .
72	" "	6 35 19	.2745254	282 26 25.5	8 41.89	+ 2 31 16.0	+ 42.06	59 59.8	. .
73	1677, Mar. 9	12 17 7	.5118886	64 39 50.8	7 10.02	+ 0 16 32.4	− 38.05	54 34.8	. .
74	1678, Feb. 27	7 21 0	.3062500	63 40 50.7	7 30.25	− 1 18 24.0	− 38.51	55 52.3	. .
75	" "	8 33 0	.3562500	64 18 21.3	7 29.64	− 1 21 36.7	− 38.40	55 50.1	. .
76	" Mar. 28	8 0 0	.3333333	84 31 3.1	7 22.44	− 3 11 13.0	− 31.55	55 16.8	. .
77	" Sept. 24	7 6 32	.2962038	284 49 30.4	8 24.43	+ 4 48 9.2	+ 17.43	58 54.0	. .
78	" Oct. 29	8 35 38	.3580787	37 3 53.8	8 32.75	− 0 0 59.9	− 47.41	59 20.6	. .
79	1679, Mar. 29	13 36 0	.5666667	220 9 55.3	7 16.28	+ 1 9 1.8	+ 39.25	54 46.5	. .
80	" "	16 0 0	.6666667	221 22 42.0	7 17.00	+ 1 15 34.0	+ 39.13	54 48.7	. .
81	" June 4	15 1 30	.6260416	30 4 4.0	8 34.62	− 0 17 59.6	− 46.33	59 32.9	. .
82	" "	16 0 0	.6666667	30 38 54.6	8 34.55	− 0 21 7.6	− 46.28	59 32.6	. .
83	" June 24	9 51 42	.4109028	284 41 24.6	8 16.01	+ 4 57 36.9	+ 7.89	58 8.5	. .
84	" "	10 32 29	.4392245	285 4 50.0	8 16.26	+ 4 57 58.9	+ 7.61	58 9.4	. .
85	1680, Jan. 16	9 1 21	.3759375	128 15 55.5	7 55.78	− 4 31 28.2	+ 17.99	56 56.7	. .
86	" "	10 7 1	.4215394	128 52 2.9	7 55.16	− 4 30 05.0	+ 18.33	56 54.9	. .
87	" Apr. 4	10 18 22	.4294213	91 23 11.7	8 19.25	− 5 14 43.4	− 6.41	58 33.3	. .
88	" Sept. 13	15 0 53	.6256134	64 54 25.7	8 35.38	− 4 46 29.7	− 20.27	59 30.0	. .
89	" Nov. 7	7 50 43	.3268866	64 33 16.1	9 9.83	− 4 39 27.6	− 20.47	61 18.4	. .
90	1681, Jan. 1	6 27 41	.2692245	64 53 53.2	8 58.16	− 4 45 23.1	− 15.37	60 40.3	. .
91	" "	7 36 41	.3171412	65 36 51.3	8 58.45	− 4 46 35.7	− 14.86	60 41.2	. .

No.	Date.	Greenwich Mean Time.		Geocentric Long. of Moon.	Motion in $0^d.01$.	Geocentric Lat. of Moon.	Motion in $0^d.01$.	Parallax.	Motion in $0^d.01$.
		h m s		° ′ ″	′ ″	° ′ ″	″	′ ″	″
92	1682, Feb. 15	7 4 31	.2948033	63 27 54.5	8 21.37	− 5 17 40.1	+ 0.80	58 40.1	. .
93	" Mar. 14	9 45 35	.4066551	61 48 36.0	8 14.82	− 5 14 55.9	− 0.43	58 13.8	. .
94	" "	10 57 35	.4566551	62 29 50.4	8 15.14	− 5 14 56.7	+ 0.03	58 15.2	. .
95	1683, Jan. 9	8 41 32	.3621759	65 19 27.0	8 18.13	− 4 54 29.8	+ 15.99	58 25.3	. .
96	" "	9 54 47	.4130440	66 1 42.3	8 19.14	− 4 53 6.5	+ 16.59	58 28.1	. .
97	" Feb. 5	11 57 42	.4984027	61 51 25.5	7 58.01	− 5 3 33.0	+ 13.24	50 20.7	. .
98	" "	12 47 44	.5331482	62 19 7.6	7 58.66	− 5 2 46.4	+ 13.63	57 22.7	. .
99	" Apr. 2	8 43 44	.3637037	79 16 42.7	7 54.48	− 4 3 47.7	+ 25.18	57 7.8	. .
100	" "	9 43 34	.4052546	79 49 34.9	7 54.84	− 4 2 1.7	+ 25.56	57 9.4	. .
101	" May 4	9 55 23	.4134606	145 25 17.1	8 29.87	+ 1 24 1.1	+ 43.16	59 22.3	. .
102	" "	10 40 55	.4450811	145 52 10.3	8 30.05	+ 1 26 17.7	+ 43.11	59 22.9	. .
103	1684, July 12	2 16 0	.0944444	110 36 32.9	7 55.60	+ 0 20 56.7	+ 43.79	57 7.9	. .
104	" "	4 40 0	.1944445	111 55 53.3	7 56.53	+ 0 28 15.1	+ 43.80	57 11.4	. .
105	" Dec. 21	9 24 59	.3923496	90 28 46.8	7 21.68	− 0 39 6.3	+ 40.50	55 1.2	. .
106	" "	10 0 59	.4173496	90 47 11.0	7 21.83	− 0 37 24.8	+ 40.58	55 1.8	. .
107	1685, Oct. 17	9 29 28	.3954630	85 44 7.8	7 3.68	+ 0 26 56.1	+ 37.92	54 8.1	. .
108	1686, Apr. 10	9 33 29	.3982523	230 0 25.1	8 31.42	+ 1 51 9.8	− 42.78	59 16.3	. .
109	" "	10 45 29	.4482523	230 43 2.6	8 31.63	+ 1 47 35.3	− 42.99	59 17.3	. .
110	" June 25	9 45 41	.4067245	149 21 46.0	7 14.74	+ 5 8 36.7	+ 7.17	54 35.3	. .
111	" July 2	9 13 35	.3844329	240 53 20.4	8 42.11	+ 0 49 10.9	− 47.12	60 1.9	. .
112	1687, Mar. 28	13 30 37	.5629282	189 6 30.7	7 27.08	+ 3 31 22.9	− 29.07	55 15.7	. .
113	" May 11	1 0 0	.0416667	51 0 17.9	8 3.84	− 0 3 55.5	+ 44.69	57 38.1	. .
114	" "	2 12 0	.0916667	51 40 36.1	8 3.30	− 0 0 12.1	+ 44.63	57 36.2	. .
115	1689, May 21	9 29 11	.3952662	100 17 0.4	8 40.67	+ 5 7 29.9	+ 2.94	59 42.1	. .
116	" Sept. 13	3 20 0	.1388889	171 20 55.5	7 37.78	+ 1 19 54.6	− 40.86	56 1.5	. .
117	" "	4 32 0	.1888889	171 59 3.4	7 37.31	+ 1 16 30.4	− 40.87	55 59.9	. .
118	1690, Apr. 13	11 28 55	.4784143	86 7 20.7	8 41.57	+ 5 12 56.4	+ 0.17	59 47.8	. .
119	" July 2	14 59 9	.6244097	55 17 48.6	8 47.90	+ 4 34 51.1	+ 19.48	60 11.0	. .
120	1699, Aug. 18	13 35 19	.5661921	64 56 16.9	8 27.31	− 4 57 48.5	− 14.50	59 1.6	. .
121	" "	14 13 19	.5925810	65 18 35.3	8 27.53	− 4 58 26.7	− 14.33	59 2.6	. .
122	" Sept. 22	20 0 0	.8333333	179 10 45.4	8 18.85	+ 0 33 20.3	+ 45.83	58 31.4	. .
123	" "	22 24 0	.9333333	180 33 48.5	8 17.88	+ 0 40 57.7	+ 45.59	58 27.9	. .
124	1701, Aug. 23	12 0 0	.5000000	29 51 8.5	7 9.26	− 5 2 58.4	− 11.16	54 16.1	. .
125	" "	13 12 0	.5500000	30 26 54.8	7 9.44	− 5 3 53.5	− 10.84	54 16.9	. .
126	" Sept. 22	17 50 5	.7431134	65 49 34.4	7 23.48	− 4 49 46.9	+ 13.67	55 11.9	. .
127	" "	18 36 24	.7752778	66 13 21.0	7 23.63	− 4 49 2.1	+ 13.98	55 13.0	. .
128	1704, July 27	1 20 0	.0555556	78 11 32.3	7 12.29	− 0 14 15.1	+ 39.03	54 36.0	. .
129	" "	2 32 0	.1055556	78 47 32.8	7 12.04	− 0 10 59.8	+ 39.02	54 34.9	. .
130	1705, Aug. 4	15 14 37	.6351505	313 18 20.6	9 3.10	− 4 48 34.4	− 13.65	60 52.9	. .
131	" Sept. 2	11 39 35	.4858218	334 36 37.7	9 11.81	− 4 58 22.8	+ 6.23	61 22.6	. .
132	1706, Jan. 23	11 4 14	.4612732	64 28 16.4	8 4.38	+ 1 10 23.8	+ 41.60	57 49.6	. .
133	" "	11 40 14	.4862732	64 48 27.7	8 4.20	+ 1 12 7.8	+ 41.53	57 48.8	. .
134	" Jan. 27	11 22 33	.4739931	117 2 23.9	7 38.50	+ 4 35 26.8	+ 15.90	55 53.8	− 0.39
135	" Apr. 21	8 51 49	.3693172	143 36 0.9	7 18.52	+ 5 12 27.8	− 6.32	54 53.5	. .
136	" "	9 45 24	.4065278	144 3 13.2	7 18.30	+ 5 12 3.9	− 6.58	54 52.4	. .
137	" May 11	20 20 0	.8472222	50 15 43.5	8 55.10	+ 0 31 40.3	+ 49.21	60 39.5	. .
138	" "	22 44 0	.9472222	51 44 50.3	8 54.53	+ 0 39 51.9	+ 48.98	60 37.2	. .
139	" May 24	10 38 30	.4434028	212 34 39.4	7 8.44	+ 1 5 40.3	− 38.59	54 16.9	. .
140	" Nov. 17	11 48 5	.4917246	23 58 34.0	8 58.96	− 1 3 12.8	+ 48.64	60 56.5	. .

No.	Date.	Greenwich Mean Time.		Geocentric Long. of Moon.	Motion in $0^d.01$.	Geocentric Lat. of Moon.	Motion in $0^d.01$.	Parallax.	Motion in $0^d.01$.
		h m s		° ′ ″	′ ″	° ′ ″	″	′ ″	″
141	1707, Apr. 4	8 11 52	.3415741	43 25 40.5	8 56.18	+ 1 33 35.0	+ 47.32	60 44.9	. .
142	" Sept. 3	7 37 33	.3177431	245 43 16.4	7 6.49	− 3 51 23.8	− 25.90	54 14.7	. .
143	" "	8 25 45	.3512153	246 7 3.8	7 6.42	− 3 52 50.3	− 25.68	54 14.6	. .
144	1708, Feb. 23	7 8 22	.2974769	359 32 41.6	7 52.93	− 0 46 37.3	+ 42.52	56 59.5	. .
145	" Sept. 6	9 27 6	.3938195	63 53 15.7	8 17.34	+ 4 46 48.5	+ 19.23	58 28.1	. .
146	" Sept. 13	6 30 0	.2708333	162 55 38.5	8 38.18	+ 1 26 22.1	− 45.98	59 39.0	. .
147	" "	8 54 0	.3708333	164 21 55.5	8 37.46	+ 1 18 40.8	− 46.31	59 36.2	. .
147*a*	" "	18 30 0	.7708333	170 5 36.7	8 33.83	+ 0 47 36.2	− 46.90	59 24.2	. .
147*b*	" "	20 54 0	.8708333	171 31 8.6	8 32.86	+ 0 39 46.8	− 46.94	59 20.9	. .
148	1709, Apr. 20	7 41 6	.3202083	166 46 11.2	8 34.73	+ 0 11 9.0	− 46.68	59 33.2	. .
149	" Sept. 16	10 40 0	.4444444	331 3 52.5	7 4.80	− 0 51 49.8	+ 38.69	54 0.8	. .
150	" "	11 52 0	.4944444	331 39 16.3	7 4.84	− 0 48 36.0	+ 38.76	54 0.9	. .
151	" Sept. 23	8 9 11	.3397106	54 59 50.1	7 40.33	+ 5 4 3.8	+ 11.07	56 10.2	+0.42
152	" "	8 57 11	.3730439	55 25 25.5	7 40.55	+ 5 4 40.2	+ 10.78	56 11.4	. .
153	" Dec. 14	5 0 0	.2083333	54 30 10.7	7 54.62	+ 4 57 43.4	+ 6.96	56 56.0	. .
154	" "	7 24 0	.3083333	55 49 26.6	7 56.03	+ 4 58 48.3	+ 6.02	57 0.4	. .
155	1710, Dec. 4	4 32 58	.1895602	54 42 23.6	7 19.78	+ 4 58 13.0	− 6.47	54 44.0	. .
156	" "	5 44 58	.2395602	55 19 3.7	7 20.14	+ 4 57 39.4	− 6.92	54 45.1	+0.23
157	1711, Sept. 30	15 20 0	.6388889	55 35 7.9	7 6.53	+ 4 35 39.9	− 15.51	54 4.8	. .
158	" "	17 44 0	.7388889	56 46 13.8	7 6.42	+ 4 33 0.8	− 16.20	54 4.7	. .
159	1712, May 15	11 6 58	.4631713	170 24 29.7	8 1.54	− 4 36 20.2	− 18.88	57 32.9	. .
160	" "	11 46 11	.4904051	170 46 21.9	8 2.11	− 4 37 11.6	− 18.73	57 34.4	. .
161	1713, Dec. 1	11 49 4	.4924074	68 5 59.5	7 46.49	+ 0 53 38.8	− 42.47	56 33.6	. .
162	1714, Mar. 20	9 6 39	.3796180	65 15 35.8	7 57.47	+ 0 32 12.2	− 41.93	57 29.7	. .
163	" Mar. 21	10 16 9	.4278819	78 55 26.1	7 41.20	− 0 40 13.7	− 40.50	56 32.6	. .
164	" Apr. 6	15 17 21	.6370486	278 55 14.8	8 7.33	+ 2 29 27.0	+ 38.01	58 2.8	. .
165	" "	16 30 36	.6879167	279 36 37.2	8 7.87	+ 2 32 40.6	+ 37.82	58 4.9	. .
166	" Sept. 27	9 0 40	.3754630	61 49 47.1	8 20.36	− 0 4 38.7	− 44.79	58 49.7	. .
167	" Oct. 2	14 37 51	.6096181	129 8 26.9	7 16.14	− 4 45 8.5	− 14.32	54 43.6	. .
168	1715, May 2	19 12 0	.8000000	40 47 52.7	9 3.46	+ 0 51 30.0	− 49.54	61 7.8	. .
169	" June 22	2 0 0	.0830000	337 38 50.1	8 16.84	+ 4 54 41.2	− 13.94	58 23.0	. .
170	" July 21	14 49 43	.6178588	9 59 6.5	8 29.00	+ 3 4 20.6	− 35.77	59 14.0	. .
171	" "	15 42 30	.6545139	10 30 13.4	8 29.08	+ 3 2 9.2	− 35.98	59 14.3	. .
172	" July 24	13 28 39	.5615625	51 34 10.1	8 26.88	− 0 22 52.3	− 44.78	59 10.4	. .
173	" "	14 14 26	.5933565	52 1 1.6	8 26.81	− 0 25 14.5	− 44.70	59 10.1	. .
174	" Aug. 15	11 46 34	.4906713	335 28 18.4	8 36.13	+ 4 41 49.5	− 15.78	59 21.0	. .
175	" "	12 31 41	.5220023	335 55 16.4	8 36.20	+ 4 40 59.3	− 16.26	59 21.9	. .
176	" Oct. 9	7 55 53	.3304745	335 21 17.1	8 34.69	+ 4 47 33.2	− 19.04	59 24.3	. .
177	" Dec. 30	7 17 35	.3038773	335 58 5.1	7 59.02	+ 4 32 20.1	− 18.98	57 20.4	. .
178	1717, Sept. 25	8 53 38	.3705787	65 5 39.7	8 14.12	− 4 36 58.0	− 22.10	58 13.9	. .
179	" "	9 45 58	.4069213	65 35 35.2	8 14.53	− 4 38 17.3	− 21.82	58 14.9	. .
180	1718, Jan. 15	13 24 33	.5587153	105 0 54.2	9 7.74	− 4 49 15.7	+ 14.69	61 9.9	. .
181	" Feb. 9	6 22 14	.2654398	65 35 40.9	8 12.80	− 4 53 48.8	− 15.13	58 12.6	. .
182	" Feb. 14	6 50 0	.2847222	139 19 12.4	9 10.12	− 3 4 15.8	+ 40.38	61 25.9	. .
183	" Sept. 9	8 33 19	.3564699	347 0 19.2	7 5.56	− 0 5 15.3	− 39.39	54 1.4	. .
184	1719, Apr. 22	7 33 37	.3150116	66 20 37.3	7 29.35	− 5 5 1.1	+ 0.79	55 22.4	. .
185	" "	8 23 6	.3493750	66 46 21.3	7 29.60	− 5 4 57.6	+ 1.08	55 23.3	. .
186	" Aug. 21	7 34 50	.3158565	231 6 30.9	8 26.56	+ 5 15 17.2	+ 5.46	58 59.1	. .
187	" Oct. 30	8 37 27	.3593403	65 12 51.8	7 16.36	− 4 56 10.8	+ 6.91	54 33.3	. .

No.	Date.	Greenwich Mean Time.		Geocentric Long. of Moon	Motion in $0^d.01$.	Geocentric Lat. of Moon.	Motion in $0^d.01$.	Parallax.	Motion in $0^d.01$.
		h m s		° ′ ″	′ ″	° ′ ″	″	′ ″	″
188	1719, Oct. 30	9 33 45	.3984375	65 41 17.7	7 16.50	− 4 55 43.1	+ 7.21	54 33.9	. .
189	" Nov. 26	6 55 20	.2884259	61 14 15.9	7 18.70	− 4 56 4.9	+ 6.15	54 36.9	. .
190	1720, Apr. 20	12 15 0	.5104167	186 10 58.6	8 57.19	+ 3 53 48.6	+ 29.71	60 41.3	+0.20
191	" "	12 43 48	.5304167	186 28 53.3	8 57.37	+ 3 54 48.0	+ 29.57	60 42.1	+0.26
192	" Dec. 31	3 0 0	.1250000	311 24 1.9	8 36.24	− 1 2 7.0	− 46.58	59 38.3	. .
193	" "	4 12 0	.1750000	312 7 0.7	8 35.52	− 1 5 59.6	− 46.34	59 35.6	. .
194	1722, Dec. 8	1 30 0	.0625000	255 58 21.3	8 20.94	+ 0 41 39.6	− 45.88	58 38.5	. .
195	1724, May 22	5 48 0	.2416667	61 59 10.6	8 56.44	+ 0 34 11.6	+ 49.28	60 44.3	. .
196	" "	7 0 0	.2916667	62 43 51.6	8 56.18	+ 0 38 18.2	+ 49.20	60 43.2	. .
197	1725, Feb. 19	12 16 12	.5112500	60 8 2.4	8 27.28	+ 1 44 5.5	+ 42.23	59 13.0	. .
198	1726, Jan. 18	7 0 0	.2916667	128 5 17.2	9 4.72	+ 4 49 53.6	− 12.09	61 0.4	. .
199	" "	8 12 0	.3416667	128 50 40.8	9 4.25	+ 4 48 51.3	− 12.71	60 59.0	. .
200	1727, Feb. 27	6 52 30	.2864584	53 56 22.0	7 46.11	+ 4 12 43.3	+ 25.52	56 41.5	. .
201	" Sept. 6	13 48 0	.5750000	55 5 0.6	7 32.66	+ 4 44 10.5	+ 18.62	55 48.8	+0.41
202	" "	15 0 0	.6250000	55 42 46.4	7 33.17	+ 4 45 42.8	+ 18.23	55 50.8	+0.41
203	" "	16 12 0	.6750000	56 20 34.8	7 33.78	+ 4 47 13.2	+ 17.86	55 52.7	+0.40
204	1728, Aug. 26	14 28 35	.6031829	55 42 16.2	7 13.48	+ 5 14 22.2	+ 5.31	54 36.5	. .
205	1729, Dec. 3	15 0 0	.6250000	56 13 57.5	7 8.54	+ 4 47 52.6	− 12.28	54 2.2	. .
206	1733, Mar. 22	5 31 55	.2304977	92 58 9.1	8 4.78	− 2 30 39.3	− 37.49	57 53.8	. .
207	" Mar. 25	5 26 36	.2268056	131 59 57.7	7 35.40	− 4 44 16.9	− 14.56	55 51.8	. .
208	1736, Apr. 14	8 18 41	.3463079	66 28 27.9	7 51.42	− 4 34 4.5	− 21.26	56 47.8	. .
209	" Aug. 1	16 13 12	.6758334	65 46 55.5	7 53.76	− 4 45 5.3	− 16.21	57 3.5	. .
210	" "	17 25 14	.7258565	66 26 27.1	7 54.59	− 4 46 26.2	− 15.86	57 6.2	. .
211	" Oct. 22	12 43 39	.5303125	66 1 50.2	7 35.29	− 4 51 35.0	− 14.67	55 45.9	. .
212	" "	13 58 30	.5822917	66 41 17.0	7 35.62	− 4 52 50.2	− 14.18	55 47.4	. .
213	1737, May 7	7 40 55	.3195081	137 52 3.5	8 9.53	− 2 24 48.8	+ 38.38	58 10.9	. .
213a	" May 22	13 55 13.3	.5800151	349 23 3.9	7 7.82	− 0 23 23.4	− 37.77	54 22.0	. .
213b	" July 22	11 34 32.6	.4823217	64 4 54.3	7 23.70	− 5 8 48.5	− 4.01	55 7.1	. .
214	1738, Jan. 2	4 18 0	.1791667	63 21 18.7	7 13.91	− 5 6 30.9	+ 1.60	54 26.1	. .
215	" "	6 42 0	.2791667	64 33 38.9	7 14.41	− 5 6 11.0	+ 2.41	54 27.8	. .
216	" "	9 6 0	.3791667	65 46 4.4	7 14.99	− 5 5 42.7	+ 3.22	54 29.6	+0.16
217	" "	11 30 0	.4791667	66 58 35.5	7 15.56	− 5 5 6.1	+ 4.03	54 31.4	+0.17
218	" Feb. 2	6 8 35	.2559607	109 32 40.8	7 42.06	− 3 24 10.2	+ 32.26	56 15.0	. .
219	" Aug. 8	13 0 0	.5416667	63 13 7.1	7 7.57	− 5 9 18.1	+ 8.51	54 11.8	. .
220	" "	15 24 0	.6416667	64 24 21.8	7 7.61	− 5 7 48.6	+ 9.33	54 11.8	. .
221	" "	20 12 0	.8416667	66 46 51.8	7 7.61	− 5 4 25.7	+ 10.88	54 11.8	. .
222	" Oct. 2	9 56 23.7	.4141632	65 41 42.6	7 8.65	− 4 54 25.3	+ 10.80	54 13.1	. .
223	" "	10 56 44.3	.4560682	66 11 38.5	7 8.54	− 4 53 39.4	+ 11.09	54 12.9	. .
224	" Dec. 23	5 24 32	.2253703	65 27 45.8	7 7.61	− 4 43 45.5	+ 15.23	54 0.7	. .
225	" "	6 24 33	.2670485	65 57 27.1	7 7.57	− 4 42 41.3	+ 15.54	54 0.5	. .
225a	1739, Feb. 15	6 50 49	.2852893	59 16 41.5	7 12.32	− 5 1 7.4	+ 12.27	54 29.9	. .
226	" Aug. 4	2 36 0	.1083333	131 3 14.7	7 8.94	+ 0 48 39.2	+ 39.15	54 14.5	. .
227	" "	5 0 0	.2083333	132 14 46.5	7 9.30	+ 0 55 10.9	+ 39.15	54 15.8	. .
228	" Oct. 23	11 39 40.0	.4858796	112 41 42.4	7 4.58	− 0 24 38.0	+ 37.42	54 15.1	. .
229	" "	12 50 20.2	.5349560	113 16 26.1	7 4.48	− 0 21 34.2	+ 37.47	54 14.9	. .
230	" Oct. 24	11 9 43.0	.4650810	124 14 36.1	7 4.98	+ 0 36 32.6	+ 37.31	54 16.7	. .
231	" "	12 16 5.0	.5111690	124 47 15.2	7 5.05	+ 0 39 24.6	+ 37.30	54 17.1	. .
232	1746, Mar. 26	8 0 0	.3333333	57 3 15.9	7 12.14	+ 4 43 8.3	+ 17.62	54 27.3	. .
233	1747, Jan. 20	13 0 0	.5416667	57 22 22.3	7 8.15	+ 5 7 33.1	+ 5.74	54 13.2	. .
234	" July 30	12 0 0	.5000000	56 23 42.2	7 7.93	+ 5 14 50.4	− 0.02	54 13.3	. .

Observations by FLAMSTEED.

These observations are used as printed in Volume I of the *Historia Coelestis Britannica*. His clock seems to have been rather inferior to those of his French contemporaries, while its correction was less carefully and regularly determined. For this purpose he appears to have depended entirely on altitudes of sun or stars observed with a quadrant, and to have made no effort whatever to eliminate possible constant errors by observations on both sides of the meridian. To this we have to add the fact that typographical errors in the *Historia Coelestis* are so numerous that uncertainties frequently arise from them. It is therefore hardly possible to form a judgment of the probable errors of the clock-corrections.

It does not appear necessary to reprint the observations in full; but we present the clock-errors resulting from the individual altitudes in the following table:—

Individual Corrections to Flamsteed's Clock, as given by Altitudes.

Date.	Greenwich Mean Time.	Correction.	Date.	Greenwich Mean Time.	Correction.	Date.	Greenwich Mean Time.	Correction.
	h m s	*m s*		*h m s*	*m s*		*h m s*	*m s*
1676, Mar. 18	7 41 34	+ 12 4	1676, Aug. 30	20 12 26	+ 4 28	1682, Mar. 11	21 30 4	− 5 30
	44 11	12 1		13 36	4 26		33 0	5 30
	47 41	12 6		14 45	4 30		35 54	5 24
	49 54	12 4				Mar. 14	11 0 37	− 5 42
Mar. 22	10 13 59	+ 4 12	Nov. 9	6 46 56	− 3 40		2 23	5 42
	17 18	3 51		51 19	3 42		4 25	5 43
	20 43	3 56		53 31	3 41		6 32	5 44
	23 10	3 58	1677, Mar. 9	7 50 41	− 0 22	1683, Feb. 3	6 13 24	− 1 52
	11 17 19	3 47		51 56	0 23		15 34	1 54
Mar. 24	7 57 38	+ 4 18		53 13	0 25		17 44	1 51
	8 7 29	4 14		55 47	0 25	Feb. 5	9 5 46	− 2 4
	8 17 12	4 27	Mar. 11	7 20	− 0 7		7 54	2 4
June 26	5 9 23	+ 6 11					10 9	2 4
	28 49	6 16	1678, Oct. 28	7 12 43	− 5 51		12 27	2 3
	48 28	6 29		19 12	5 52		14 48	2 4
30	5 26 30	+ 8 47		22 27	5 49	Apr. 1	20 17 15	− 5 50
	31 22	8 46		28 58	5 54		19 33	5 53
Aug. 19	3 36 9	+ 5 43	Oct. 29	11 25 5	− 6 11		21 53	5 52
	38 27	5 44		28 22	− 6 12	6	20 40	− 5 51
	43 3	5 48	1680, Jan. 16*	7 22 0	+ 11 16	30	20 5	− 6 1
	20 25 8	+ 5 23		27 15	11 23	May 6	19 45	− 5 59
	28 33	5 19		31 8	11 25			
	30 51	5 15		34 45	11 23	1686, Apr. 9	20 20	− 8 34
	35 31	5 18		38 9	+ 11 21	20	20	− 12 52

* Clock losing about 32^s per day on mean time.

Clock-corrections for FLAMSTEED'S *Eclipses.*

	h	*m s*		*h*	*m s*		*h*	*m s*
1676, June 0,	29.1	−2 10	1684, July 8,	5	− 4 28	1689, Sept. 5,	1.8	+1 29
1,	5.6	−1 46	12,	5	− 3 40	Sept. 12,	3.9	+1 49
			1687, May 6,	20.0	−12 25		20.0	+2 5
			1687, May 11,	4.5	−14 30			

Longitudes and Latitudes of Stars for 1850.

Adopted obliquity for 1850, 23° 27′ 31″.4.

Name of star.	Long., 1850.	L'	μ_1	Lat., 1850.	B'	B''	μ_2
	° ′ ″	″	″	° ′ ″	″	″	″
δ Piscium	12 3 4.56	5027.30	+ 3.75	+ 2 10 24.09	+ 7.77	+ 0.17	− 7.33
o Piscium	25 38 41.10	5030.82	+ 4.45	− 1 37 54.11	+ 17.45	+ 0.14	− 7.71
Lalande 4903 . . .	. . . .	. . . .	. .	. . . . .	. .	. .	. .
ρ^3 Arietis	44 49 28.02	5044.77	+ 20.13	+ 1 10 34.52	+ 9.95	+ 0.08	− 26.88
B. A. C. 920 . . .	. . . .	. . . .	. .	. . . . .	. .	. .	. .
ε Arietis	46 24 19.42	5021.59	− 1.59	+ 4 9 31.65	+ 37.45	+ 0.08	− 0.18
δ Arietis	48 45 10.95	5037.80	+ 13.40	+ 1 48 35.34	+ 35.01	+ 0.07	− 3.75
ζ Arietis	49 51 1.50	5018.76	− 5.17	+ 2 52 40.69	+ 31.99	+ 0.07	− 7.27
f Tauri	51 29 47.81	5028.22	+ 0.40	− 5 55 55.76	+ 39.62	+ 0.06	− 0.37
9 Tauri	55 20 44.37	5020.92	− 2.89	+ 3 42 22.55	+ 35.94	+ 0.05	− 5.62
16 g Pleiadum (Celaeno) .	57 20 27.90	5023.46	− 0.21	+ 4 20 58.47	+ 36.30	+ 0.04	− 6.01
17 b Pleiadum (Electra) .	57 19 04.12	5023.52	− 0.21	+ 4 10 27.23	+ 36.29	+ 0.04	− 6.01
m Pleiadum	57 32 36.36	5023.29	− 0.20	+ 4 52 3.00	+ 36.37	+ 0.04	− 6.01
19 e Pleiadum (Taygeta) .	57 28 14.20	5023.42	− 0.20	+ 4 30 9.03	+ 36.34	+ 0.04	− 6.01
20 c Pleiadum (Maia) . .	57 35 10.48	5023.47	− 0.20	+ 4 22 27.82	+ 36.38	+ 0.04	− 6.01
23 d Pleiadum (Merope) .	57 36 18.62	5023.63	− 0.20	+ 3 56 24.61	+ 36.38	+ 0.04	− 6.02
η Tauri	57 53 53.58	5023.62	− 0.19	+ 4 2 6.94	+ 36.49	+ 0.04	− 6.02
27 f Pleiadum (Atlas) . .	58 15 42.32	5023.61	− 0.17	+ 3 54 6.42	+ 36.61	+ 0.04	− 6.03
h Pleiadum	58 17 6.70	5023.68	− 0.17	+ 3 58 55.08	+ 36.61	+ 0.04	− 6.03
33 Tauri	59 51 0.18	5030.00	+ 5.63	+ 2 39 45.27	+ 39.93	+ 0.03	− 3.25
A^1 Tauri	61 21 28.80	5032.66	+ 7.80	+ 1 14 40.94	+ 33.68	+ 0.03	− 9.98
53 Tauri	64 33 37.15	5027.41	+ 2.09	− 0 17 56.98	+ 38.81	+ 0.01	− 5.77
ω^2 Tauri	63 58 0.04	5019.68	− 5.77	− 0 46 3.73	+ 40.10	+ 0.02	− 4.32
51 Tauri	64 23 28 69	5033.59	+ 8.40	+ 0 10 23.27	+ 38.34	+ 0.02	− 6.20
γ Tauri	63 42 22.34	5038.67	+ 11.24	− 5 44 56.14	+ 39.53	+ 0.02	− 4.81
56 Tauri	64 42 26.60	5026.36	+ 1.20	+ 0 18 57.33	+ 38.50	+ 0.01	− 6.12
58 Tauri	63 48 36.36	5038.00	+ 11.02	− 6 18 24.08	+ 39.17	+ 0.02	− 5.21
χ Tauri	66 1 17.99	5027.84	+ 3.58	+ 4 0 13.10	+ 40.55	+ 0.01	− 4.39
κ^1 Tauri	66 6 22.07	5032.90	+ 7.81	+ 0 36 38.91	+ 37.66	+ 0.01	− 7.31
κ^2 Tauri	66 6 6.55	5035.98	+ 10.87	+ 0 30 59.01	+ 36.87	+ 0.01	− 8.09
70 Tauri	65 8 54.07	5034.35	+ 7.65	− 5 40 14.95	+ 40.80	+ 0.01	− 3.92
71 Tauri	65 16 9.35	5036.06	+ 9.28	− 6 1 2.85	+ 39.51	+ 0.01	− 5.24
B. A. C. 1373 . . .	66 36 19.67	5035 49	+ 10.21	− 0 9 4.89	+ 36.56	+ 0.01	− 8.52
ε Tauri	66 21 58.47	5035.64	+ 9.78	− 2 35 1.21	+ 38.74	+ 0.01	− 6.19
θ^1 Tauri	65 51 22.57	5035.39	+ 8.72	− 5 45 43.06	+ 40.43	+ 0.01	− 4.48
θ^2 Tauri	65 51 46.13	5036.73	+ 10.04	− 5 51 19.42	+ 40.75	+ 0.01	− 4.16
B. A. C. 1391 . . .	66 21 57.39	5033.81	+ 7.22	− 5 36 22.08	+ 39.93	+ 0.01	− 5.10
α Tauri	67 41 34.13	5029.58	+ 3.12	− 5 28 40.80	+ 25.40	0.00	− 19.88
τ Tauri	70 3 34.50	5024.60	− 0.51	+ 0 41 43.81	+ 42.72	0.00	− 3.10
o Tauri	80 24 6.36	5026.21	+ 0.91	− 1 18 39.46	+ 45.25	− 0.04	− 1.77
119 Tauri	81 18 3.38	5026.47	+ 1.09	− 4 42 19.15	+ 46.41	− 0.04	− 0.64
120 Tauri	81 36 38.28	5026.22	+ 0.86	− 4 46 26.76	+ 47.44	− 0.04	+ 0.37
136 Tauri	86 25 24.56	5026.52	+ 1.10	+ 4 9 44.95	+ 46.02	− 0.06	− 1.00
χ^2 Orionis	86 42 50.31	5024.11	− 0.95	− 3 42 13.34	+ 44.65	− 0.06	− 2.36
H Geminorum . . .	88 51 7.95	5025.18	− 0.06	− 0 11 15.80	+ 36.66	− 0.07	− 10.21
3 Geminorum . . .	90 8 36.04	5025.07	− 0.14	− 0 19 34.47	+ 45.04	− 0.07	− 1.71
Lalande 12148 . .	. . . .	. . .	. .	. . . . .	. .	. .	. .

Longitudes and Latitudes of Stars for 1850—Continued.

Name of star.	Long., 1850.	L'	μ_1	Lat., 1850.	B'	B''	μ_2
	° ′ ″	″	″	° ′ ″	″	′	″
μ Geminorum . . .	93 12 18.48	5032.00	+ 6.88	− 0 50 5.32	+ 34.42	− 0.08	− 11.97
η Geminorum . . .	91 20 40.91	5019.48	− 5.66	− 0 54 24.95	+ 44.98	− 0.07	− 1.65
ν Geminorum . . .	94 42 30.93	5023.30	− 1.44	− 3 4 29.55	+ 43.96	− 0.09	− 2.20
Weisse II, 1656 . .	. . . .	. . . .	. .	. . . . .	. .	. .	. .
λ Geminorum . . .	106 41 13.63	5019.62	− 3.74	− 5 39 4.60	+ 37.54	− 0.09	− 5.69
f Geminorum . . .	111 34 53.38	5022.17	− 1.61	− 3 45 40.41	+ 41.94	− 0.14	+ 0.45
g Geminorum . . .	112 59 52.92	5017.39	− 6.77	− 2 39 43.70	+ 33.82	− 0.14	− 7.10
85 Geminorum . . .	114 57 20.30	5022.61	− 2.24	− 0 53 44.84	+ 36.24	− 0.14	− 3.87
λ Cancri	119 43 15.34	5026.29	− 1.08	+ 4 21 55.07	+ 33.19	− 0.16	− 4.72
δ Cancri	126 37 33.12	5029.15	+ 3.87	+ 0 4 20.97	+ 11.19	− 0.17	− 23.09
α Cancri	131 32 49.20	5026.07	+ 3.82	− 5 5 32.66	+ 28.29	− 0.18	− 3.12
κ Cancri	134 4 34.96	5020.48	− 1.20	− 5 34 54.38	+ 29.06	− 0.18	− 0.77
ξ Leonis	139 33 22.76	5015.35	− 7.73	− 3 9 42.60	+ 15.07	− 0.19	− 11.11
o Leonis	142 9 32.41	5009.35	− 13.24	− 3 45 49.64	+ 16.07	− 0.19	− 8.31
η Leonis	145 48 34.08	5027.87	− 0.92	+ 4 51 25.06	+ 21.42	− 0.19	− 0.35
α Leonis	147 44 39.90	5001.63	− 23.95	+ 0 27 35.91	+ 11.37	− 0.20	− 8.98
B. A. C. 3579 . . .	151 31 38.50	5021.65	− 7.00	+ 4 27 58.41	+ 12.73	− 0.20	− 4.79
τ Leonis	169 25 0.41	5025.93	+ 1.24	− 0 33 20.10	+ 1.45	− 0.20	− 1.78
e^1 Leonis	172 16 59.92	5022.17	+ 1 63	− 5 42 12.52	+ 0.33	− 0.20	− 0.57
γ Virginis	188 4 4.71	4974.25	− 53.22	+ 2 48 15.20	− 35.46	− 0.17	− 23.50
α Virginis	201 44 55.24	5020.21	− 3.55	− 2 2 35.62	− 27.94	− 0.15	− 5.54
λ Virginis	214 51 31.61	5022.20	− 3.35	+ 0 30 10.41	− 30.89	− 0.11	+ 0.30
α^1 Libræ	222 56 3.05	5015.02	− 10.42	+ 0 22 51.99	− 47.68	− 0.09	− 11.83
α^2 Libræ	222 59 29.42	5016.06	− 9.37	+ 0 21 7.60	− 47.08	− 0.09	− 11.22
γ Libræ	233 2 25.27	5033.81	+ 6.74	+ 4 24 7.06	− 39.21	− 0.06	+ 1.42
π Scorpii	240 50 46.83	5022.08	− 1.44	− 5 27 21.05	− 48.53	− 0.03	− 5.04
β^1 Scorpii	241 5 43.84	5025.33	− 0.23	+ 1 1 36.85	− 47.50	− 0.03	− 3.93
B. A. C. 5395 . . .	243 17 19.10	5013.38	− 11.81	− 0 11 6.60	− 43.51	− 0.02	+ 0.70
τ Scorpii	249 21 47.33	5024.37	+ 0.55	− 6 6 1.12	− 49.99	0.00	− 4.30
δ Sagittarii	. . . .	. . . .	. .	. . . . .	. .	. .	. .
ξ^2 Sagittarii	281 21 19.59	5027.25	+ 2.44	+ 1 40 49.86	− 47.20	+ 0.11	− 2.41
o Sagittarii	282 53 48.46	5030.00	+ 5.00	+ 0 52 52.20	− 51.68	+ 0.11	− 7.30
π Sagittarii	284 9 28.01	5022.53	− 2.28	+ 1 27 24.42	− 47.84	+ 0.11	− 3.83
ρ^1 Sagittarii	237 21 25.77	5020.22	− 3.60	+ 4 14 26.80	− 42.93	+ 0.12	+ 0.08
ρ^2 Sagittarii	287 19 46.63	5032.85	+ 8.87	+ 3 47 1.60	− 54.20	+ 0.12	− 11.17
33 Capricorni	314 46 35.20	5022.12	− 6.54	− 5 18 38.24	− 41.79	+ 0.18	− 12.41
γ Capricorni	319 41 18.20	5043.47	+ 16.61	− 2 32 35.89	− 30.24	+ 0.19	− 4.11
e^2 Aquarii	328 23 27.70	5030.25	+ 4.81	− 0 16 28.65	− 21.39	+ 0.20	− 1.49
o Aquarii	333 17 36.95	5023.39	− 2.79	− 1 13 13.67	− 18.11	+ 0.20	− 1.94
κ Aquarii	337 19 40.03	5010.35	− 11.63	+ 4 7 8.56	− 21.64	+ 0.20	− 8.62
τ^2 Aquarii	336 30 1.80	5026.35	− 3.35	− 5 39 28.56	− 17.55	+ 0.20	− 3.88
B. A. C. 8184 . . .	349 7 9.75	5035.12	+ 8.95	− 1 7 49.10	− 32.16	+ 0.20	− 28.66

NOTE.—These positions of the occulted stars are derived from an unpublished discussion, in which the several standard catalogues are reduced to the equinox of my paper *On the Right Ascensions of the Equatorial Fundamental Stars* (1872), and in which the positions of most of the stars observed by BRADLEY are from Dr. AUWERS's re-reduction of BRADLEY's observations.

Details of Reduction of the Occultations.

These are presented in the following tables in such form as to give as great facility as appeared practicable to any one desiring to re-examine and correct the work. Each observed occultation is numbered, so as to facilitate subsequent reference; the arrangement is not, however, chronological, except through each series. The different series are arranged in the order of their computation, as it did not seem necessary to run a risk of confusion in seeking to make them more nearly chronological. The only serious displacement occurs in the case of FLAMSTEED'S observations, which, in strictness, should immediately follow those of HEVELIUS. The following are the only parts of the table which seem to need explanation.

The data for local and Greenwich mean times have been already pretty fully given, and, in most cases, the results are given in preceding sections, and are here simply copied from them. Small discrepancies may be found in some cases, as the definitive discussion was not completed till after a great deal of the computation of the following tables was made. Any corrections thus required can be readily made in the equations.

The sidereal times are in all cases from the mean equinox of the date, nutation being omitted.

The column "Moon's Tabular Geocentric Position" gives the longitude and latitude of the moon as derived from HANSEN'S tables, and printed on pages 197 to 201. The longitude is counted from the mean equinox of the date, as in the case of the sidereal time.

The apparent tabular position of the moon's centre as seen from the place of observation is then deduced from the geocentric position by the method described in § 6. The upper line of each pair gives the longitude and latitude of the moon; the lower one, those of the star. The latter have been derived from the positions of the stars just given by reducing them to the date, and correcting for aberration.

Next we find the tabular differences of apparent longitude and latitude of the moon and star, formed by subtraction from the two preceding columns.

In the next column we have, in the upper line of each pair, the apparent semidiameter of the moon as seen from the place of observation, using OUDEMANS'S value of the ratio of the diameter of the moon to that of the earth. The lower line gives the tabular distance of the centre of the moon from the star, deduced from the numbers of the preceding column. If the observations and all the elements of reduction were correct, these two numbers should be identical. The expression of the difference in terms of the elements which the observations will enable us to correct is the work of the following section.

The last column gives, in the upper line of each pair, the longitude of the sun at the time of the observation, and, in the lower line, the elongation of the star east of the sun. The latter number affords the argument for taking out the aberration of the star from the proper table, and for determining whether the phenomenon was observed at the bright or the dark limb of the moon.

Tabular Exhibit of Reduction of the Occultations.

OCCULTATIONS OBSERVED BY BULLIALDUS.

No.	Star occulted. [Place of obs.]	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	☉ $L-$☉
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
1	α Leonis . . .	1627,	9 29 42	9 29 22	144 30 40.5	144 7 15.6	+0 34 25.8	. .	938.4	86.3
	[Loudon.]	June 17	15 12 50	. . .	+1 23 59.4	144 39 4.1	+0 27 9.8	. .	. .	58.4
2	η Tauri, I. . .	1634,	5 44 4	5 43 44	54 24 14.8	54 44 56.6	+4 12 15.0	− 555.9	960.6	279.2
	[Loudon.]	Dec. 30	0 20 33	. . .	+4 46 35.2	54 54 12.5	+4 0 49.7	+ 685.3	881.5	135.7
3	τ Tauri, I. . .	1639,	9 9 42	9 0 21	67 33 17.7	66 50 19.4	+0 36 9.7	− 998.3	922.5	17.8
	[Paris.]	Apr. 7	10 13 13	. . .	+1 7 55.4	67 6 57.7	+0 40 13.4	− 243.7	1028.6	49.3
4	ε Tauri, I. . .	1641,	8 13 4	8 3 43	. . . .	63 13 57.0	−2 28 30.9	− 764.7	888.2	24.1
	[Paris.]	Apr. 13	9 42 7	. . .	. . . .	63 26 41.7	−2 36 23.0	+ 472.1	898.0	39.3
	GASSENDUS.									
5	α Leonis, I. . .	1627,	10 30 0	10 5 3	144 50 9.0	144 24 50.8	+0 34 51.0	− 853.3	935.4	86.3
	[Digne.]	June 17	16 13 16	. . .	+1 25 40.8	144 39 4.1	+0 27 9.7	+ 461.3	970.0	58.4
6	ξ Sagittarii, I. .	1627,	10 54 17	10 29 20	278 37 23.8	277 59 43.8	+1 46 48.4	− 931.1	903.0	175.6
	[Digne.]	Sept. 18	22 44 17	. . .	+2 26 51.8	278 15 14.9	1 42 31.9	+ 256.5	965.4	102.7
7	Mars, I. . . .	1632,	15 18 39	15 9 18	136 30 12.4	136 14 12.2	+4 20 32.8	− 569.0	945.1	316.6
	[Paris.]	Feb. 5	12 21 29	. . .	+4 58 18.5	136 23 41.2	+4 33 30.6	− 777.8	962.6	179.8
8	Mars, E. . . .	1632,	15 47 15	15 37 54	136 46 3.2	136 27 35.8	+4 18 16.0	+ 250.5	944.3	. .
		Feb. 5	12 50 9	. . .	+4 58 9.5	136 23 25.3	+4 33 30.6	− 914.6	948.0	. .
9	γ Capricorni, I. .	1635,	*9 47 49	9 22 52	316 30 0.9	316 26 44.7	−2 19 36.7	− 887.6	982.3	153.3
	[Digne.]	Aug. 26	20 7 14	. . .	−1 26 9.6	316 41 32.3	−2 31 30.2	+ 713.5	1138.3	163.
10	Pl. Electra, (b) I.	1637,	8 48 58	8 27 11	54 54 41.1	54 3 10.4	+4 13 45.8	−1056.3	979.6	9.4
	[Aix.]	Mar. 29	9 18 49	. . .	+4 38 53.2	54 20 46.7	+4 9 11.2	+ 274.6	1088.6	45.
11	Pl. Maia, (c) I. .	1637,	9 22 47	9 1 0	55 14 58.4	54 23 15.0	+4 10 34.3	− 818.2	978.0	. .
		Mar. 29	9 52 43	. . .	+4 38 11.0	54 36 53.2	+4 21 11.6	− 637.3	1035.4	. .
12	Pl. Merope, (d) I.	1637,	9 32 21	9 10 34	55 20 43.7	54 29 6.2	+4 9 37.1	− 534.9	977.6	. .
		Mar. 29	10 2 30	. . .	+4 37 59.0	54 38 1.1	+3 55 8.4	+ 868.7	1019.4	. .
13	η Tauri, I. . .	1637,	9 48 54	9 27 7	55 30 38.3	54 39 20.2	+4 7 58.6	− 976.0	976.8	9.4
		Mar. 29	10 18 55	. . .	+4 37 38.3	54 55 36.2	+4 0 50.5	+ 428.1	1063.6	45.5
14	Pl. Merope, I. .	1638,	7 39 34	7 17 47	54 34 5.4	54 23 5.6	+3 49 12.9	− 958.3	973.3	304.9
	[Aix.]	Jan. 24	3 55 58	. . .	+4 7 54.8	54 39 3.9	+3 55 9.1	− 356.2	1020.3	109.7
15	η Tauri, I. . . [Aix.]	1638,	8 35 10	8 13 23	55 06 05.6	54 45 30.0	+3 48 54.3	− 668.9	972.6	304.9
		Jan. 24	4 51 42	. . .	+4 6 4.9	54 56 38.9	+4 0 51.2	− 716.9	979.4	110.0
16	μ Geminorum, I.	1638,	16 36 34	16 11 37	90 40 36.3	90 00 48.0	−0 47 19.5	− 897.2	979.2	269.0
	[Digne.]	Dec. 20	10 35 29	. . .	−0 15 22.0	90 15 45.2	−0 51 18.4	+ 238.9	928.4	181.7

* This local time should be increased by 2^m 23^s. See page 82.

Tabular Exhibit of Reduction of the Occultations—Continued.

HEVELIUS AT DANTZIG.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	⊙ $L-⊙$
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
17	α Tauri, I. . .	1644,	14 50 9	13 35 33	64 59 57.9	64 33 28.8	−5 36 14.6	− 993.2	1009.0	233.0
		Nov. 14	6 28 51	. . .	−5 0 50.5	64 50 2.0	−5 29 32.7	− 401.9	1066.3	191.8
18	α Tauri, E. . .	1644,	15 50 39	14 36 3	65 38 3.4	65 4 39.0	−5 36 32.5	+ 877.0	1007.4	. .
		Nov. 14	7 29 31	. . .	−5 0 43.5	64 50 2.0	−5 29 32.7	− 419.8	967.8	. .
19	α Tauri, I. . .	1645,	13 33 6	12 18 30	64 27 23.1	64 33 49.9	−5 31 39.5	−1010.5	995.5	195.8
		Oct. 8	2 44 46	. . .	−4 51 50.4	64 50 40.4	−5 29 31.3	− 128.2	1013.7	229.0
20	α Tauri, E. . .	1645,	14 43 0	13 28 44	65 9 57.4	65 6 45.1	−5 27 53.0	+ 964.7	996.2	. .
		Oct. 8	3 54 51	. . .	−4 50 37.9	64 50 40.4	−5 29 31.3	− 98.3	965.2	. .
21	B. A. C. 920 . .	1656,	8 34 45	7 20 9	44 7 19.2	43 25 48.1	+4 26 39.9	. .	931.4	341.6
		Mar. 1	7 15 36	. . .	+4 54 8.4	. . .	. . .	. .	. .	62
22	53 Tauri, I. . .	1658,	11 6 55	9 52 19	61 25 40.1	61 42 17.8	−0 30 3.0	− 686.0	893.0	202.5
		Oct. 14	0 41 15	. . .	+0 8 6.0	61 53 43.8	−0 19 11.0	− 652.0	946.4	219.4
23	β Scorpii, E. . .	1660,	14 38 37	13 24 1	238 38 45.5	238 40 11.4	+1 11 54.5	+ 776.9	964.3	37.0
		Apr. 26	17 1 22	. . .	+2 8 20.5	238 27 14.5	+1 3 6.7	+ 527.8	939.2	201.4
24	α Virginis, I. .	1660,	10 56 25	9 41 49	199 0 38.4	198 54 19.0	−2 11 23.9	− 732.7	927.7	87.0
		June 17	16 43 35	. . .	−1 16 33.4	199 6 31.7	−2 1 43.8	− 580.1	934.4	112.1
25	71 Tauri, I. . .	1663,	9 39 25	8 24 49	63 8 12.9	62 26 29.5	−5 51 7.6	− 768.8	980.4	354.0
		Mar. 14	9 8 57	. . .	−5 14 0.6	62 39 18.3	−6 2 20.5	+ 672.9	1018.5	67.1
26	θ^2 Tauri, I. . .	1663,	10 32 7	9 17 31	63 39 46.6	62 56 45.4	−5 53 19.2	−1088.7	978.3	. .
		Mar. 14	10 1 48	. . .	−5 14 21.2	63 14 54.1	−5 52 37.4	− 41.8	1083.8	. .
27	θ^1 Tauri, I. . .	1663,	10 35 7	9 20 31	63 41 34.8	62 58 32.1	−5 53 27.6	− 960.9	978.2	. .
		Mar. 14	10 4 48	. . .	−5 14 22.4	63 14 33.0	−5 47 0.5	− 387.1	1031.3	. .
28	e^2 Aquarii, I.	1663,	9 15 37	8 1 1	325 32 21.2	325 36 9.8	−0 26 21.9	− 687.3	924.2	145.6
		Aug. 18	19 4 4	. . .	+0 25 5.0	325 47 37.1	−0 15 47.5	− 634.4	935.2	180.2
29	e^2 Aquarii, E. .	1663,	10 5 31	8 50 55	325 59 0.5	325 57 8.2	−0 27 59.6	+ 571.1	925.6	. .
		Aug. 18	19 54 6	. . .	+0 25 25.9	325 47 37.1	−0 15 47.5	− 732.1	928.8	. .
30	α Tauri, I. . .	1664,	9 24 20	8 9 44	65 31 39.9	64 49 36.8	−5 34 27.5	− 966.4	969.8	11.6
		Mar. 31	10 3 51	. . .	−4 55 42.3	65 5 43.2	−5 29 29.7	− 297.8	1007.2	53.5
31	α Tauri, E. . .	1664,	10 16 6	9 1 30	66 2 8.9	65 20 18.0	−5 35 55.2	+ 874.8	967.8	. .
		Mar. 31	10 55 45	. . .	−4 54 58.5	65 5 43.2	−5 29 29.7	− 385.5	952.3	. .
32	Not identified .	1671,	9 3 34	7 48 58	46 30 41.8	45 43 50.9	+3 2 55.8	. .	989.0	354.0
		Mar. 14	8 33 15	. . .	+3 35 38.8	. . .	. . .	. .	. .	52.3
33	Not identified .	1671,	9 6 37	7 52 1	46 32 33.2	45 45 38.2	+3 2 57.3	. .	988.9	. .
		Mar. 14	8 36 19	. . .	+3 35 46.3	. . .	. . .	. .	. .	. .
34	Not identified .	1671,	9 55 25	8 40 49	47 2 12.4	46 15 0.5	+3 2 29.4	. .	986.5	. .
		Mar. 14	9 25 15	. . .	+3 37 46.4	. . .	. . .	. .	. .	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

HEVELIUS AT DANTZIG—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ $b'-B$	S' D	☉ $L-$☉
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
35	α Virginis, I.	1671,	10 47 1	9 32 25	198 40 21.9	199 0 50.5	−2 5 5.2	− 897.6	889.4	32.4
		Apr. 22	12 50 45	. . .	−1 21 22.1	199 15 48.1	−2 1 46.4	− 198.8	918.7	166.9
36	α Virginis, E.	1671,	11 56 30	10 41 54	199 14 31.7	199 26 19.6	−2 11 39.2	+ 631.5	889.1	. .
		Apr. 22	14 0 26	. . .	−1 24 22.7	199 15 48.1	−2 1 46.4	− 592.8	865.8	. .
37	Pl. Cel., 16 *g*, I.	1672,	12 36 33	11 21 57	54 47 19.4	54 37 6.5	+4 28 33.6	− 925.7	1004.8	223.9
		Nov. 5	3 40 15	. . .	+4 57 57.4	54 52 32.2	+4 19 54.1	+ 519.5	1059.5	191.5
38	Pl. Tay., 19 *e*, I.	1672,	12 48 18	11 33 42	54 54 37.2	54 42 42.0	+4 29 2.0	−1056.6	1004.7	. .
		Nov. 5	3 52 2	. . .	+4 58 3.0	55 0 18.6	+4 29 4.6	− 2.6	1053.4	. .
39	Pl. Maia, 20 *c*, I.	1672,	13 7 4	11 52 28	55 6 16.2	54 51 39.7	+4 29 45.2	− 935.1	1004.6	. .
		Nov. 5	4 10 51	. . .	+4 58 11.9	55 7 14.8	+4 21 23.3	+ 501.9	1058.8	. .
40	Pl. Tay., 19 *e*, I.	1673,	8 5 16	6 51 10	55 30 31.7	54 49 24.9	+4 41 21.0	− 640.8	963.3	2.5
		Mar. 22	8 8 51	. . .	+5 10 52.8	55 0 5.7	+4 29 6.0	+ 735.0	974.5	52.5
41	Pl. Tay., 18 *m*, I.	1673,	8 8 46	6 54 10	55 32 15.8	54 50 58.8	+4 41 13.4	− 808.5	963.2	. .
		Mar. 22	8 11 53	. . .	+5 10 53.0	55 4 27.3	+4 51 0.2	− 586.8	996.5	. .
42	Pl. Ast., 21 *k*, I.	1673,	8 19 46	7 5 10	55 38 36.3	54 56 44.8	+4 40 45.0	− 831.2	962.8	. .
		Mar. 22	8 22 54	. . .	+5 10 53.4	55 10 36.0	+4 32 5.1	+ 519.9	978.2	. .
43	Pl. Ast., 22 *l*, I.	1673,	8 24 46	7 10 10	55 41 29.1	54 59 22.7	+4 40 31.1	− 764.5	962.7	. .
		Mar. 22	8 27 55	. . .	+5 10 53.6	55 12 7.2	+4 30 6.0	+ 625.1	985.8	. .
44	Pl. Elec., 17 *b*, I.	1674,	13 41 29	12 26 53	54 20 22.6	54 37 12.8	+4 3 26.0	− 907.3	923.4	150.6
		Aug. 23	23 51 42	. . .	+4 42 56.3	54 52 20.1	+4 9 24.4	− 358.4	973.4	264.3
45	Pl. Cel., 16 *g*, I.	1674,	14 8 59	12 54 23	54 34 48.2	54 49 36.5	+4 4 38.5	− 247.4	924.4	. .
		Aug. 23	0 19 16	. . .	+4 42 23.0	54 53 43.9	+4 19 55.9	− 917.4	949.5	. .
46	Pl. Mer., 23 *d*, I.	1674,	14 25 59	13 11 23	54 43 43.0	54 56 56.3	+4 5 22.6	− 758.3	925.0	. .
		Aug. 23	0 36 19	. . .	+4 42 2.5	55 9 34.6	+3 55 22.1	+ 600.5	965.8	. .
47	Pl. Cel., 16 *g*, E.	1674,	14 32 29	13 17 53	54 47 9.2	54 59 56.7	+4 5 42.6	+ 372.8	925.1	. .
		Aug. 23	0 42 50	. . .	+4 41 58.2	54 53 43.9	+4 19 55.9	− 853.3	929.0	. .
48	Pl. Maia, 20 *e*, I.	1674,	14 43 59	13 29 23	54 53 10.9	55 4 53.7	+4 6 10.9	− 212.8	925.5	. .
		Aug. 23	0 54 22	. . .	+4 41 44.0	55 8 26.5	+4 21 25.3	− 914.4	938.4	. .
49	Pl. Elec., 17 *b*, E.	1674,	14 51 29	13 36 53	54 57 7 2	55 8 6.3	+4 6 29.2	+ 946.2	925.7	. .
		Aug. 23	1 1 53	. . .	+4 41 34.7	54 52 20.1	+4 9 24.4	175.2	959.8	. .
50	Pl. Alcy., 25 *η*, T.	1674,	15 1 29	13 46 53	55 2 22.6	55 12 21.3	+4 6 52.9	888.3	926.0	. .
		Aug. 23	1 11 55	. . .	+4 41 22.1	55 27 9.6	+4 1 4.4	+ 348.5	952.2	. .
51	Pl. Maia, 20 *c*, E.	1674,	15 4 29	13 49 53	55 3 56.5	55 13 36.5	+4 7 0.3	+ 310.1	926.1	150.6
		Aug. 23	1 14 56	. . .	+4 41 18.6	55 8 26.4	+4 21 25.3	− 865.0	918.4	264.5
52	Pl. Mer., 23 *d*, E.	1674,	15 16 49	14 2 13	55 10 25.3	55 18 47.0	+4 7 28.2	+ 552.5	926.4	. .
		Aug. 23	1 27 18	. . .	+4 41 3.3	55 9 34.5	+3 55 22.1	+ 726.1	911.6	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

HEVELIUS AT DANTZIG—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	⊙ $L-$⊙
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
53	Pl. Alcy., 25 η, E.	1674,	16 8 24	14 53 48	55 37 31.0	55 39 53.0	+4 9 12.2	+ 763.6	927.6	. .
		Aug. 23	2 19 1	. . .	+4 39 59.3	55 27 9.4	+4 1 4.4	+ 487.8	904.5	. .
54	. . . .	1675,	8 8 32	6 53 56	111 30 48.8	112 6 31.2	−0 39 22.1	. .	974.0	291.4
		Jan. 11	3 33 45	. . .	−0 6 15.5	. . . .	. . . .	. .	. .	179.9
55	85 Geminorum, I.	1675,	8 43 2	7 28 26	111 51 1.7	112 23 49.0	−0 40 11.8	− 447.4	974.5	. .
		Jan. 11	4 8 21	. . .	−0 8 7.7	112 31 16.4	−0 54 48.7	+ 876.9	984.5	. .
56	Anonymous . .	1675,	8 59 7	7 44 31	112 0 27.5	112 31 41.5	−0 40 40.5	. .	975.9	. .
		Jan. 11	4 24 29	. . .	−0 9 0.0	. . . .	. . . .	. .	. .	. .
57	85 Geminorum, E.	1675,	9 16 52	8 2 16	112 10 51.8	112 40 15.4	−0 41 16.5	+ 539.0	976.5	. .
		Jan 11	4 42 16	. . .	−0 9 57.7	112 31 16.4	−0 54 48.7	+ 812.2	974.7	. .
58	Mars, I. . . .	1676,	13 34 33	12 19 57	77 26 45.4	77 53 31.0	−0 30 11.0	− 932.6	895.3	159.3
		Aug. 31	0 18 20	. . .	+0 9 19.3	78 9 3.6	−0 28 0.4	− 130.6	941.6	278.1
59	Mars, E. . . .	1676,	14 45 48	13 31 12	78 1 52.8	78 24 51.7	−0 29 33.9	+ 873.6	897.6	. .
		Aug. 31	1 29 46	. . .	+0 6 12.7	78 10 18.1	−0 27 57.1	− 96.8	878.8	. .
60	B. A. C. 1714? .	1676,	14 52 54	13 38 18	78 5 22.7	78 27 50.3	−0 29 31.2	. .	897.8	. .
		Aug. 31	1 36 54	. . .	+0 5 54.1	. . . .	. . . .	. .	. .	. .
61	. . . .	1678,	7 37 52	6 23 16	83 41 30.8	83 19 58.9	−3 40 14.2	. .	914.7	8.3
		Mar. 28	8 3 43	. . .	−3 7 41.1	. . . .	. . . .	. .	. .	75.4
62	χ Orionis, I. . .	1678,	9 22 52	8 8 16	84 35 17.1	84 4 44.3	−3 47 33.1	− 854.8	911.9	. .
		Mar. 28	9 49 0	. . .	−3 11 31.1	84 18 59.1	−3 43 31.5	− 241.6	886.5	. .
63	a^1 Libræ, I . .	1679,	14 50 30	13 35 54	220 9 52.1	220 19 26.0	+0 18 42.2	− 854.4	901.1	8.9
		Mar. 29	15 20 31	. . .	+1 9 1.5	220 33 40.4	+0 24 12.5	− 330.3	916.4	211.6
64	a^2 Libræ, I. . .	1679,	14 58 10	13 43 34	220 13 44.3	220 22 18.5	+0 18 46.7	− 886.3	901.1	. .
		Mar. 29	15 28 13	. . .	+1 9 22.4	220 37 4.8	+0 22 27.6	− 220.9	913.2	. .
65	a^1 Libræ, E. . .	1679,	16 6 10	14 51 34	220 48 4.9	220 48 9.5	+0 19 59.5	+ 869.1	900.5	. .
		Mar. 29	16 36 23	. . .	+1 12 28.0	220 33 40.4	+0 24 12.5	− 253.0	905.3	. .
66	a^2 Libræ, E. . .	1679,	16 14 45	15 0 9	220 52 25.8	220 51 29.2	+0 20 11.4	+ 864.4	900.6	. .
		Mar. 29	16 44 59	. . .	+1 12 51.3	220 37 4.8	+0 22 27.6	− 136.2	875.0	. .
67	Jupiter, I. . .	1679,	16 16 6	15 1 30	30 4 4.0	30 19 1.4	−1 11 57.0	. .	979.9	73.9
		June 4	21 10 30	. . .	−0 17 59.6	. . . .	. . . .	. .	. .	316.2
68	Jupiter, E. . .	1679,	17 14 17	15 49 41	30 38 43.3	. . . .	. . . .	. .	981.8	. .
		June 4	22 8 51	. . .	−0 21 6.6	. . . .	. . . .	. .	. .	. .
69	ρ Sagittarii, I. .	1679,	11 6 18	9 51 42	284 41 24.5	284 50 22.3	+4 1 59.7	− 526.2	955.1	93.0
		June 24	17 18 42	. . .	+4 57 36.9	284 59 8.5	+4 15 40.2	− 820.5	974.5	191.7
70	ρ Sagittarii, E. .	1679,	11 47 5	10 32 29	285 4 50.0	285 8 8.5	+4 2 16.9	+ 540.0	955.9	. .
		June 24	17 59 36	. . .	+4 57 58.9	284 59 8.5	+4 15 40.2	− 803.3	967.2	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ $b'-B$	S' D	⊙ $L-$⊙
	HEVELIUS AT DANTZIG—Continued.									
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	′	°
71	α Tauri, I. . .	1681,	7 42 17	6 27 41	64 53 53.2	65 2 47.2	−5 26 08.8	−1046.9	1005.4	282.2
		Jan. 1	2 30 9	. . .	−4 45 23.2	65 20 14.1	−5 29 22.7	+ 193.9	1060.0	142.7
72	α Tauri, E. . .	1681,	8 51 17	7 36 41	65 36 51.3	65 36 23.4	−5 24 41.4	+ 969.3	1006.5	. .
		Jan. 1	3 39 20	. . .	−4 46 35.7	65 20 14.1	−5 29 22.7	+ 281.3	1005.0	. .
73	α Tauri, I. . .	1683,	9 56 8	8 41 32	65 19 27.0	65 4 42.4	−5 28 57.0	−1031.8	968.3	289.9
		Jan. 9	5 14 1	. . .	−4 54 29.8	65 21 54.2	−5 29 22.0	+ 25.0	1025.7	135.4
74	α Tauri, E. . .	1683,	11 9 23	9 54 47	66 1 42.3	65 37 17.1	−5 27 0.8	+ 922.9	967.9	. .
		Jan. 9	6 27 28	. . .	−4 53 6.6	65 21 54.2	−5 29 22.0	+ 141.2	928.6	. .
75	119 Tauri, I. . .	1683,	9 58 20	8 43 44	79 16 42.7	78 40 7.4	−4 43 30.0	−1089.6	939.7	13.3
		Apr. 2	10 43 27	. . .	−4 3 47.7	78 58 17.0	−4 43 35.5	+ 5.5	1086.2	66.0
76	120 Tauri, I. . .	1683,	10 34 56	9 20 20	79 36 49.1	78 59 55.9	−4 44 6.8	−1016.2	938.6	13.3
		Apr. 2	11 20 9	. . .	−4 2 42.9	79 16 52.1	−4 47 46.1	+ 219.3	1036.7	66.3
77	119 Tauri, E. . .	1683,	10 58 10	9 43 34	79 49 35.0	79 12 56.0	−4 44 30.8	+ 879.0	937.8	. .
		Apr. 2	11 43 27	. . .	−4 2 1.7	78 58 17.0	−4 43 35.5	− 55.3	878.2	66.5
	THE CASSINIS AND OTHERS AT THE PARIS OBSERVATORY.									
78	τ Scorpii, I. . .	1672,	10 27 42.6	10 18 21.6	246 54 51.4	246 38 9.8	−6 4 47.5	− 915.5	887.2	130.9
		Aug. 2	19 16 41.9	. . .	−5 13 26.2	246 53 25.3	−6 4 35.0	− 12.5	910.[illegible]	116.0
79	85 Geminorum .	1675,	8 18 18	8 8 57	112 14 47.4	112 53 11.7	−0 38 25.4	. .	974.8	291.4
		Jan. 11	. . . .	. . .	−0 10 19.5	112 31 16.4	−0 54 48.7	. .	. .	180
80	e Leonis, I. . .	1676,	10 32 18	10 22 57	169 3 17.2	169 39 32.0	−5 30 38.7	− 741.4	981.0	340.8
		Feb. 29	9 10 19.4	. . .	−4 56 59.7	169 51 53.4	−5 42 13.4	+ 694.7	1013.3	189.1
81	e Leonis, E. . .	1676,	11 29 24	11 20 3	169 37 32.6	170 5 52.1	−5 34 46.8	+ 838.7	983.0	. .
		Feb. 29	10 7 34.8	. . .	−4 57 31.9	169 51 53.4	−5 42 12.7	+ 445.9	946.4	. .
82	Saturn, I. . .	1678,	7 30 21	. . .	63 40 50.7	63 17 51.9	−1 43 27.7	. .	925.9	. .
		Feb. 27	6 2 1.3	. . .	−1 18 24.2	. . . .	. . . .	. .	. .	. .
83	Saturn, E. . .	1678,	8 42 21	. . .	64 18 21.3	63 46 19.3	−1 47 15.8	. .	923.5	. .
		Feb. 27	7 14 13.1	. . .	−1 21 36.7	. . . .	. . . .	. .	. .	. .
84	Lalande 12148 .	1680,	10 27 43	10 18 22	91 23 11.3	90 45 12.0	−5 55 17.6	. .	963.4	16.0
		Apr. 4	11 23 50.4	. . .	−5 15 13.5	. . . .	. . . .	. .	. .	75.4
85	γ Tauri, I. . .	1683,	12 13 50.6	12 4 29.6	61 55 11.7	61 10 41.2	−5 35 1.2	− 700.8	943.0	317.4
		Feb. 5	9 18 43.5	. . .	−5 3 26.7	61 22 22.0	−5 46 4.1	+ 662.9	962.5	104.0
86	μ Geminorum, I.	1684,	9 34 17.8	9 24 56.8	90 28 46.0	90 50 17.3	−1 5 55.1	− 240.5	911.4	271.0
		Dec. 21	3 39 24.7	. . .	−0 39 6.3	90 54 17.8	−0 51 2.4	− 892.7	924.1	179.9
87	μ Geminorum, E.	1684,	10 8 10.7	9 58 49.7	90 46 35.7	91 3 8.1	−1 3 15.3	+ 530.3	912.1	. .
		Dec. 21	4 13 23.2	. . .	−0 37 31.4	90 54 17.8	−0 51 2.4	− 732.9	904.5	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

THE CASSINIS AND OTHERS AT THE PARIS OBSERVATORY—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ $b'-B$	S' D	$\odot$ $L-\odot$
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
88	B. A. C. 3579, I.	1686,	9 55 2	9 45 41	149 21 46.0	149 2 2.1	+4 18 59 1	− 756.1	895.9	94.6
		June 25	16 12 34.3	. . .	+5 8 36.6	149 14 38.2	+4 27 38.4	− 519.3	915.4	54.6
89	B. A. C. 5395 .	1686,	9 22 56	9 13 35	240 53 20.4	241 2 45.7	−0 6 2.2	+ 104.7	988.2	101.3
		July 2	16 7 59.0	. . .	+0 49 10.0	241 1 1.0	−0 9 55.5	+ 235.3	. .	139.7
90	W. II, 1656 . .	1689,	9 38 37	9 29 16	100 17 3.6	99 42 8.6	+4 20 42.3	. .	980.2	61.4
		May 21	13 39 11.9	. . .	+5 7 30.0	. . .	. . .	. .	. .	38
91	136 Tauri, E. .	1690,	11 38 16	11 28 55	85 7 20.7	84 28 59.0	+4 27 39.7	. .	980.3	24.4
		Apr. 13	13 8 24.2	. . .	+5 12 56.4	84 11 28.8	+4 8 32.6	. .	. .	59.8
92	27 Tauri, I. . .	1690,	15 8 29	14 59 8	55 17 48.1	55 46 28.5	+3 46 34.8	− 929.7	991.0	101.3
		July 2	21 54 36.1	. . .	+4 34 51.2	56 1 58.2	+3 53 7.1	− 392.3	1007.0	314.7

LA HIRE.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ $b'-B$	S' D	$\odot$ $L-\odot$
93	θ^1 Tauri, I. . .	1682,	7 13 52.2	7 4 31.2	63 27 54.6	63 13 44.5	−5 48 7.9	−1010.2	973.3	327 7
		Feb. 15	4 58 18.5	. . .	−5 17 40.1	63 30 34.7	−5 46 53.0	− 74.7	1008.2	95.8
94	θ^2 Tauri, I. . .	1682,	7 16 17.2	7 6 56.2	63 29 18.8	63 14 45.8	−5 48 4.8	− 970.0	973.3	. .
		Feb. 15	5 0 43.9	. . .	−5 17 40.0	63 30 55.8	−5 52 31.8	+ 267.0	1001.3	. .
95	μ Geminorum, I.	1684,	9 34 19.2	9 24 58.2	90 28 46.5	90 50 17.8	−1 5 55.1	− 240.1	911.4	271.0
		Dec. 21	3 39 26.1	. . .	−0 39 6.2	90 54 17.9	−0 51 2.4	− 892.7	924.2	179.9
96	μ Geminorum, E.	1684,	10 7 58.3	9 58 37.3	90 45 58.5	91 3 7.4	−1 3 15.3	+ 529.5	912.1	. .
		Dec. 21	4 13 10.8	. . .	−0 37 31.5	90 54 17.9	−0 51 2.4	− 732.9	904.2	. .
97	H Geminorum, I.	1685,	9 38 49.0	9 29 28	85 44 7.8	86 18 38.8	−0 12 22.5	− 910.5	889.1	205.2
		Oct. 17	23 26 43.3	. . .	+0 26 56.1	86 33 49.3	−0 12 16.2	− 6.3	910.5	241.3
98	α Tauri, I. . .	1699,	13 44 40.8	13 35 19.8	64 56 17.2	65 25 52.2	−5 42 42.0	− 578.1	972.5	146.1
		Aug. 18	23 35 9.6	. . .	−4 57 48.5	65 35 30.3	−5 29 17.2	− 804.8	989.5	279.5
99	α Tauri, E. . .	1699,	14 22 40.8	14 13 19.8	65 18 35.8	65 46 3.1	−5 41 18.4	+ 632.8	974.3	. .
		Aug 18	. . . .	. . .	−4 58 26.7	65 35 30.3	−5 29 17.2	− 721.2	957.4	. .
100	α Tauri, I. . .	1701,	17 59 25.3	17 50 4.3	65 49 34.8	65 27 50.1	−5 17 15.4	− 577.3	914.3	179.5
		Sept. 22	6 6 40.8	. . .	−4 49 46.9	65 37 27.4	−5 29 16.8	+ 721.4	922.5	246.1
101	α Tauri, E. . .	1701,	18 45 43.8	18 36 22.8	66 13 21.0	65 45 30.6	−5 16 33.5	+ 483.2	913.6	. .
		Sept. 22	6 53 6.9	. . .	−4 49 2.1	65 37 27.4	−5 29 16.8	+ 763.3	902.2	. .
102	Jupiter, I. . .	1715,	13 38 38.3	13 29 17.3	51 34 38.5	52 1 38.4	−1 12 28.8	. .	973.0	121.1
		July 24	. . . .	. . .	−0 22 54.8	. . .	. . . .	. .	. .	290
103	Jupiter, E. . .	1715,	14 15 3.8	14 5 42.8	51 55 54.5	. . .	. . . .	. .	974.5	. .
		July 24	. . . .	. . .	−0 24 47.4	. . .	. . . .	. .	. .	. .
104	B. A. C. 8184, I.	1718,	8 42 44.1	8 33 23.1	347 0 21.4	347 8 35.4	−0 55 5.1	− 525.1	888.7	166.6
		Sept. 9	19 56 45.2	. . .	−0 5 15.6	347 17 20.5	−1 7 6.3	+ 721.2	891.9	180.7

Tabular Exhibit of Reduction of the Occultations—Continued.

CASSINI, ETC.—SERIES II

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	$\odot$ $L-\odot$
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	′	°
105	33 Capricorni, I.	1705,	15 23 58	15 14 37	313 18 20.7	312 34 29.6	−5 30 7.4	−696.2	998.2	. .
		Aug. 4	0 17 44.2	. . .	−4 48 34.4	312 46 5.8	−5 17 37.6	−749.8	1021.1	. .
106	τ Aquarii, I. .	1705,	11 48 56	11 39 35	334 36 37.7	334 15 32.8	−5 49 17.5	−837.3	1012.0	. .
		Sept. 2	22 36 27	. . .	−4 58 2[illegible].8	334 29 30.1	−5 39 2.9	−614.6	1035.3	. .
107	τ Aquarii, E. .	1705,	12 50 19	12 40 58	335 15 49.9	334 45 11.0	−5 44 28.5	+940.9	1011.6	. .
		Sept. 2	23 38 0.3	. . .	−4 57 56.3	334 29 30.1	−5 39 2.9	−325.6	991.3	. .
108	κ^1 Tauri, I. . .	1706,	11 13 34	11 4 13	64 28 16.0	63 53 56.5	+0 45 20.2	−713.9	956.8	. .
		Jan. 23	7 24 46.5	. . .	+1 10 23.8	64 5 50.4	+0 35 44.8	+575.4	916.8	. .
109	λ Cancri, I. . .	1706,	12 31 54	12 22 33	117 34 14.5	117 29 59.4	+4 12 11.9	−784.7	927.4	. .
		Jan. 27	8 59 5.9	. . .	+4 36 33.1	117 43 4.1	+4 21 7.4	−535.5	948.2	. .
110	η Leonis, I. . .	1706,	9 1 9	8 51 48	143 36 0.5	143 35 29.8	+4 42 10.8	−771.7	910.0	. .
		Apr. 21	10 58 56.7	. . .	+5 12 27.8	143 48 21.5	+4 50 56.9	−526.1	931.8	. .

The above times have been computed using CASSINI's correction for deviation of quadrant. If, instead of this, we use the deviation found on and after May, 1706, the results will be as follows:—

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	$\odot$ $L-\odot$
111	33 Capricorni, I.	1705,	15 24 20	15 14 59	313 18 34.5	312 34 41.8	−5 30 6.6	−684.0	998.2	32.1
		Aug. 4	0 18 6.2	. . .	−4 48 34.7	312 46 5.8	−5 17 37.6	−749.0	1012.3	80.7
112	τ Aquarii, I. .	1705,	11 49 11	11 39 50	334 36 47.0	334 15 39.6	−5 49 17.0	−830.5	1012.0	60.0
		Sept. 2	22 36 42.0	. . .	−4 58 22.7	334 29 30.1	−5 39 2.9	−614.1	1029.5	74.5
113	τ Aquarii, E. .	1705,	12 50 34	12 41 13	335 15 59.4	334 45 18.3	−5 44 27.3	+948.2	1011.6	. .
		Sept. 2	23 38 15.3	. . .	−4 57 56.0	334 29 30.1	−5 39 2.9	−324.4	997.5	. .
114	κ^1 Tauri, I. . .	1706,	11 13 52	11 4 31	64 28 26.1	63 54 4.6	+0 45 19.2	−705.8	956.8	03.4
		Jan. 23	7 25 4.6	. . .	+1 10 24.6	64 5 50.4	+0 35 44.8	+574.4	909.9	20.7
115	κ^2 Tauri, I. . .	1706,	11 36 15	11 26 54	64 40 59 3	64 4 17.9	+0 45 46.6	− 72.8	956.0	. .
		Jan. 23	7 47 31.3	. . .	+1 11 29.3	64 5 30.7	+0 30 6.1	+940.5	943.3	. .
116	κ^2 Tauri, I. . .	1706,	11 36 58	11 27 37	64 41 23.5	64 4 37.9	+0 45 47.4	− 52.8	955.9	. .
		Jan. 23	7 48 14.4	. . .	+1 11 31.4	64 5 30.7	+0 30 6.1	+941.3	942.8	. .
117	κ^2 Tauri, E. . .	1706,	11 46 8	11 36 47	64 46 32.0	64 8 53.5	+0 45 55.9	+202.8	955.6	. .
		Jan. 23	7 57 25.9	. . .	+1 11 57.9	64 5 30.7	+0 30 6.1	+949.8	971.2	. .
118	λ Cancri, I. . .	1706,	12 32 12	12 22 51	117 34 24.1	117 30 6.4	+4 12 9.3	−777.7	927.4	07.5
		Jan. 27	8 59 23.8	. . .	+4 36 33.4	117 3 4.1	+4 21 7.4	−538.1	943.8	70.2
119	η Leonis, I. . .	1706,	9 1 29	8 52 8	143 36 10.5	143 35 37.7	+4 42 8.8	−763.8	910.0	31.2
		Apr. 21	10 59 16.6	. . .	+5 12 27.7	143 48 21.5	+4 50 55.5	−526.7	925.7	12.6
120	η Leonis, E. . .	1706,	9 55 5	9 45 44	144 3 23 3	143 56 7.8	+4 38 5.7	+466.3	908.9	. .
		Apr. 21	11 53 1.6	. . .	+5 12 3.8	143 48 21.5	+4 50 55.5	−769.8	899.2	. .
121	λ Virginis, I. .	1706,	10 47 51	10 38 30	212 34 39.4	212 43 0.9	+0 18 36.5	− 518.5	894.7	63.1
		May 24	14 56 2.5	. . .	+1 5 40.3	212 51 39.4	+0 30 54.7	− 738.2	902.2	149.8

Tabular Exhibit of Reduction of the Occultations—Continued.

CASSINI, ETC.—SERIES II—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ $b'-B$	S' D	⊙ $L-$⊙
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
122	ο Piscium, I. .	1706,	11 57 26	11 48 5	23 58 34.0	23 22 46.8	−1 32 54.4	− 969.5	1008.5	235.0
		Nov. 17	3 43 39.2	. . .	−1 3 12.8	23 38 56.3	−1 38 30.3	+ 335.9	1025.7	148.6
123	ρ Arietis, I. . .	1707,	8 21 13	8 11 52	43 25 52.8	42 34 14.9	+1 2 43.7	− 896.3	996.0	14.3
		Apr. 4	9 10 55.4	. . .	+1 33 36.1	42 49 11.2	+1 10 20.6	− 456.9	1005.9	28.5
124	α Scorpii, I. . .	1707,	7 46 54	7 37 33	245 43 16.4	245 31 27.7	−4 43 36 3	− 569.9	889.6	160.5
		Sept. 3	18 35 47.2	. . .	−3 51 23.8	245 40 57.6	−4 31 51.5	− 704.8	905.3	85.2
125	α Scorpii, E. . .	1707,	8 35 6	8 25 45	246 7 3.8	245 49 24.1	−4 43 54.2	+ 506.5	888.4	. .
		Sept. 3	19 24 7.1	. . .	−3 52 50.3	245 40 57.6	−4 31 51.5	− 722.7	881.6	. .
126	Venus, I_1. . .	1708,	7 17 38	7 8 17	359 32 39.2	358 41 23.2	−1 11 2.1	− 842.8	933.3	334.2
		Feb. 23	5 28 30.4	. . .	−0 46 37.1	358 55 26.0	−1 3 50.1	− 432.0	947.0	24.7
127	Venus, I_2. . . .	1708,	7 17 53	7 8 32	359 32 47.1	358 41 30.9	−1 11 1.6	− 835.9	933.3	. .
		Feb. 23	5 28 45	. . .	−0 46 37.8	358 55 26.8	−1 3 50.0	− 431.6	940.7	. .
128	χ Tauri, E. . .	1708,	9 36 16	9 26 55	63 53 22.1	64 19 54.1	+3 55 9.8	+1015.0	958.1	164.2
		Sept. 6	20 40 16	. . .	+4 46 48.6	64 2 59.1	+3 59 16.4	− 246.6	1042.2	259.9
129	τ Leonis, I. . .	1709,	7 50 27	7 41 6	166 46 11.3	167 15 49.3	−0 21 21.3	− 696.9	985.8	30.5
		Apr. 20	9 45 10.2	. . .	+0 11 9.0	167 27 26.2	−0 33 22.5	+ 721.2	1003.0	137.0
130	σ Aquarii, I. .	1709,	12 1 48	11 52 27	331 39 29.6	331 10 8.5	−1 27 16.0	− 622.4	889.8	173.7
		Sept. 16	23 44 40.2	. . .	−0 48 34.8	331 20 30.9	−1 12 49.2	− 866.8	1067.0	157.6
131	Pl. Maia, 20 c, I.	1709,	8 18 32	8 9 11	54 59 50.1	55 24 11.3	+4 14 8.6	− 816.6	921.1	180.5
		Sept. 23	20 28 23.4	. . .	+5 4 3.9	55 37 47.9	+4 21 35.6	− 447.0	928.9	235.1
132	Pl. Tay., 19 e, I.	1709,	8 22 34	8 13 13	55 1 59.0	55 26 33.6	+4 14 24.1	− 268.2	921.3	180.5
		Sept. 23	20 32 24	. . .	+5 4 7.0	55 31 1.8	+4 29 16.7	− 892.6	931.9	235.0
133	22 l, I.	1709,	8 41 24	8 32 3	55 12 1.0	55 37 30.8	+4 15 37.5	− 332.8	922.1	. .
		Sept. 23	20 51 19.1	. . .	+5 4 21.4	55 43 3.6	+4 30 16.8	− 879.3	939.9	. .
134	22 l, E.	1709,	9 5 32	8 56 11	55 24 53.7	55 51 14.0	+4 17 18.4	+ 490.4	923.2	. .
		Sept. 23	21 15 31.1	. . .	+5 4 39.5	55 43 3.6	+4 30 16.8	− 778.4	919.2	. .
135	Pl. Maia, 20 c, E.	1709,	9 8 5	8 58 44	55 26 14.8	55 52 38.9	+4 17 29.4	+ 891.0	923.3	. .
		Sept. 23	21 18 4.5	. . .	+5 4 41.4	55 37 47.9	+4 21 35.6	− 246.2	922.0	. .
136	Pl. Elec., 17 b, I.	1710,	4 42 19	4 32 58	54 42 23.6	55 8 13.1	+4 13 13.7	− 886.4	899.9	252.2
		Dec. 4	21 34 29.6	. . .	+4 58 13.0	55 22 59.5	+4 9 36.8	+ 216.9	910.3	163.2
137	22 l, I.	1710,	5 40 31	5 31 10	55 12 1.7	55 37 30.5	+4 16 35.4	− 401.3	902.4	. .
		Dec. 4	22 32 51.1	. . .	+4 57 46.0	55 44 11.8	+4 30 18.9	− 823.5	915.4	. .
138	Pl. Ast., 21 k, I.	1710,	5 49 8	5 39 47	55 16 25.3	55 41 40.0	+4 17 7.1	− 60.6	902.7	. .
		Dec. 4	22 41 49.5	. . .	+4 57 41.9	55 42 40.6	+4 32 18.0	− 910.9	912.9	. .
139	Pl. Ast., 21 k, E.	1710,	6 2 0	5 52 39	55 22 58.4	55 47 46.8	+4 17 55.5	+ 306.2	903.1	. .
		Dec. 4	22 54 23.7	. . .	+4 57 35.7	55 42 40.6	+4 32 18.0	− 862.5	915.2	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

CASSINI, ETC.—SERIES II—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star.		$l'-L$ $b'-B$	S' D	⊙ $L-$⊙
						Longitudes.	Latitudes.			
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
140	Pl. Maia, 20 *c*, E.	1710,	6 15 39	6 6 18	55 30 0.1	55 54 10.2	+4 18 47.1	+ 904.2	903.7	. .
		Dec. 4	23 8 4.9	. . .	+4 57 29.0	55 39 6.0	+4 21 37.7	− 170.6	917.6	. .
141	Pl. Maia, 20 *c*, I.	1711,	15 36 40	15 27 19	55 38 44.5	55 26 7.4	+4 14 34.4	− 813.8	897.2	186.9
		Sept. 30	4 13 24.7	. . .	+4 35 32.0	55 39 41.2	+4 21 36.4	− 422.0	914.7	228.8
142	Pl. Tay., 19 *e*, I.	1711,	15 44 39	15 35 18	55 42 41.2	55 28 53.7	+4 14 37.7	− 231.3	897.2	. .
		Sept. 30	4 21 25	. . .	+4 35 23.4	55 32 45.0	+4 29 17.8	− 880.1	909.8	. .
143	Pl. Alcyone, *η*, I.	1711,	16 47 25	16 38 4	56 13 41.1	55 50 58.5	+4 14 23.2	− 445.5	896.3	186.9
		Sept. 30	5 24 21.3	. . .	+4 34 15.1	55 58 24.0	+4 1 15.5	+ 787.7	904.4	229.1
144	Pl. Maia, 20 *c*, E.	1711,	16 52 48	16 43 27	56 16 20.6	55 52 54.4	+4 14 18.5	+ 793 2	896.3	. .
		Sept. 30	5 29 45.2	. . .	+4 34 9.0	55 39 41.2	+4 21 36.5	− 438.0	904.1	. .
145	Pl. Alcyone, *η*, E.	1711,	17 30 54	17 21 33	56 35 9.0	56 6 47.9	+4 13 28.8	+ 504.0	895.5	. .
		Sept. 30	6 7 57.4	. . .	+4 33 26.2	55 58 23.9	+4 1 15.5	+ 733.3	889.2	. .
146	*e* Leonis, I. . .	1712,	11 17 13	11 7 52	170 24 59.6	170 13 46.8	−5 28 30.3	− 492.1	947.4	54.9
		May 15	14 52 9.6	. . .	−4 36 21.7	170 21 58.9	−5 42 15.1	+ 824.8	959.2	115.5
147	*e* Leonis, E. . .	1712,	11 56 26	11 47 5	170 46 51.8	170 32 35.9	−5 30 37.0	+ 637.0	946.3	. .
		May 15	15 31 29.1	. . .	−4 37 13.1	170 21 58.9	−5 42 15.1	+ 698.1	942.2	. .
148	*o* Tauri, I. . .	1714,	10 25 29	10 16 8	78 55 25.7	78 15 54.4	−1 13 23.9	− 864.7	931.2	0.7
		Mar. 21	10 21 32.0	. . .	−0 40 13.7	78 30 19.1	−1 19 41.6	+ 377.7	943.3	77.8
149	*ξ* Sagittarii, I. .	1714,	15 26 41	15 17 20	278 55 14.3	279 12 36.4	+1 35 55.3	− 904.0	953.4	16.5
		Apr. 6	16 26 38.4	. . .	+2 29 27.0	279 27 40.4	+1 41 53.8	− 358.5	971.4	263.0
150	*ξ* Sagittarii, E. .	1714,	16 39 56	16 30 35	279 36 37.2	279 42 52.7	+1 38 3.7	+ 912.3	955.3	. .
		Apr. 6	17 40 5.5	. . .	+2 32 40.6	279 27 40.4	+1 41 53.8	− 230.1	940.4	. .
151	*δ* Piscium, I. .	1715,	14 59 4	14 49 43	9 59 6.5	9 57 55.7	+2 20 57.1	− 758.3	980.5	118.3
		July 21	22 55 54.4	. . .	+3 4 20.6	10 10 34.0	+2 10 13.3	+ 643.8	994.4	251.9
152	*δ* Piscium, E. .	1715,	15 51 51	15 42 30	10 30 13.4	10 21 33.3	+2 22 26.4	+ 659.3	981.3	. .
		July 21	23 48 50.1	. . .	+3 2 9.1	10 10 34.0	+2 10 13.3	+ 733.1	985.5	. .
153	Jupiter, I. . .	1715,	13 37 59.8	13 28 38.8	51 34 16.0	52 1 12.1	−1 12 28.7	. .	973.0	. .
		July 24	21 46 26.6	. . .	−0 22 52.8	. . .	. . .	. .	. .	. .
154	Jupiter, I. . .	1715,	13 39 15.8	13 29 54.8	51 35 0.6	52 1 56.1	−1 12 28.7	. .	973.1	. .
		July 24	21 47 42.8	. . .	−0 22 56.8	. . .	. . .	. .	. .	. .
155	Jupiter, E. . .	1715,	14 23 46.5	14 14 25.5	52 1 1.6	52 27 6.5	−1 12 14.0	. .	974.9	. .
		July 24	22 32 20.8	. . .	−0 25 14.5	. . .	. . .	. .	. .	. .
156	Jupiter, E. . .	1715,	14 25 2.5	14 15 41.5	52 1 46.0	52 27 49.0	−1 12 13.2	. .	975.0	. .
		July 24	22 33 37.0	. . .	−0 25 18.4	. . .	. . .	. .	. .	. .
157	*κ* Aquarii, I. .	1715,	11 55 55	11 46 34	335 28 18.4	335 18 56.2	+3 53 44.8	− 532.9	980.4	142.2
		Aug. 15	21 30 49.2	. . .	+4 41 49.5	335 27 49.1	+4 7 37.7	− 832.9	988.0	193.3

Tabular Exhibit of Reduction of the Occultations—Continued.

CASSINI, ETC.—SERIES II—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ $b'-B$	S' D	⊙ $L-$⊙
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
158	κ Aquarii, E.	1715,	12 41 2	12 31 41	335 55 16.3	335 38 53.9	+3 55 37.0	+664.8	981.0	. .
		Aug. 15	22 16 3.6	. . .	+4 40 59.3	335 27 49.1	+4 7 37.7	−720.7	979.4	. .
159	κ Aquarii, I.	1715,	8 5 9	7 55 48	335 21 14.1	335 14 4.7	+3 58 40.0	−827.8	981.2	195.8
		Oct. 9	21 16 15.9	. . .	+4 47 33.2	335 27 52.5	+4 7 39.0	−539.0	985.8	139.7
160	κ Aquarii, I.	1715,	7 26 56	7 17 35	335 58 5.1	335 12 49.8	+4 1 41.7	−887.1	942.8	278.4
		Dec. 30	2 1 14.1	. . .	+4 32 20.1	335 27 36.9	+4 7 39.1	−357.4	954.2	57.1
161	α Tauri, I.	1717,	9 2 58	8 53 37	65 5 58.6	65 34 44.8	−5 27 15.9	−968.0	953.4	182.5
		Sept. 25	21 21 4.6	. . .	−4 36 58.0	65 50 52.8	−5 29 12.6	+116.7	970.6	243.3
162	α Tauri, E.	1717,	9 55 18	9 45 57	65 35 34.9	66 6 26.0	−5 26 26.0	+933.2	956.9	. .
		Sept. 25	22 13 33.2	. . .	−4 38 17.2	65 50 52.8	−5 29 12.6	+166.6	943.5	. .
163	B. A. C. 8184, I.	1718,	8 42 38	8 33 17	347 0 18.3	347 8 32.3	−0 55 4.9	−528.1	888.7	166.6
		Sept. 9	19 56 39.1	. . .	−0 5 15.3	347 17 20.4	−1 7 6.4	+721.5	894.1	180.7
164	α Tauri, I.	1719,	7 42 58	7 33 37	66 20 37.3	65 38 20.2	−5 36 44.1	−805.6	910.3	31.9
		Apr. 22	9 43 54.3	. . .	−5 5 1.1	65 51 45.8	−5 29 15.1	−449.0	919.0	34.0
165	α Tauri, E.	1719,	8 32 27	8 23 6	66 46 21.3	66 3 25.8	−5 38 46.1	+700.0	908.6	. .
		Apr. 22	10 33 31.4	. . .	−5 4 57.6	65 51 45.8	−5 29 15.1	−571.0	900.8	. .
166	α Tauri, E.	1719,	9 43 5	9 33 44	65 41 17.3	66 6 35.0	−5 35 3.4	+828.0	900.0	216.7
		Oct. 30	0 17 23	. . .	−4 55 43.1	65 52 47.0	−5 29 12.9	−350.5	895.6	209.2
167	γ Tauri, I.	1719,	7 4 40	6 55 19	61 14 15.3	61 40 20.4	−5 38 14.7	−790.4	899.5	243.9
		Nov. 26	23 24 58.9	. . .	−4 56 4.8	61 53 30.8	−5 45 47.7	+453.0	907.6	178.0
168	γ Virginis, I.	1720,	12 24 2	12 14 41	186 10 47.0	186 11 16.5	+3 4 44.3	−337.3	1003.2	31.2
		Apr. 20	14 20 50.5	. . .	+3 53 48.0	186 16 53.8	+2 49 1.7	+942.6	1001.0	155.1
169	γ Virginis, E.	1720,	12 49 49	12 40 28	186 26 49.2	186 23 53.4	+3 4 4.2	+419.6	1002.7	. .
		Apr. 20	14 46 41.8	. . .	+3 54 41.2	186 16 53.8	+2 49 1.7	+902.5	995.1	. .
170	Pl. Elec., 17 *b*, I.	1727,	14 1 21	13 52 0	55 7 6.4	55 21 32.1	+4 13 4.4	−915.6	924.9	164.0
		Sept. 6	1 3 42.1	. . .	+4 44 15.7	55 36 47.7	+4 9 41.5	+202.9	935.4	251.6
171	Pl. Cel., 16 *g*, I.	1727,	14 7 11	13 57 50	55 10 9.8	55 23 55.9	+4 13 36.2	−855.6	925.0	. .
		Sept. 6	1 9 33.1	. . .	+4 44 23.2	55 38 11.5	+4 20 12.7	−396.5	941.4	. .
172	Pl. Tay., 19 *e*, I.	1727,	14 40 5	14 30 44	55 27 25.5	55 37 11.4	+4 16 28.9	−526.4	926.0	. .
		Sept. 6	1 42 32.5	. . .	+4 45 5.7	55 45 57.8	+4 29 23.1	−774.2	935.2	. .
173	Pl. Maia, 20 *c*, I.	1727,	14 42 16	14 32 55	55 28 34.0	55 38 3.3	+4 16 39.9	−890.7	926.0	. .
		Sept. 6	1 44 43.8	. . .	+4 45 8.3	55 52 54.0	+4 21 41.9	−302.0	938.2	. .
174	Pl. Elec., 17 *b*, E.	1727,	15 10 15	15 0 54	55 43 14.5	55 48 59.6	+4 18 57.8	+731.9	926.6	164.0
		Sept. 6	2 12 47.4	. . .	+4 45 43.9	55 36 47.7	+4 9 41.5	+556.3	917.6	251.8
175	Pl. Cel., 16 *g*, E.	1727,	15 20 39	15 11 18	55 48 42.1	55 53 0.7	+4 19 47.1	+889.2	926.8	. .
		Sept. 6	2 23 13.1	. . .	+4 45 57.1	55 38 11.5	+4 20 12.7	− 25.6	887.1	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ / $b'-B$	S' / D	⊙ / $L-$⊙
					CASSINI, ETC.—SERIES II—Continued.					
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
176	Pl. Tay., 19 *e*, E.	1727,	15 35 59	15 26 38	55 56 44.3	55 58 51.8	+4 20 56.0	+774.0	927.1	. .
		Sept. 6	2 38 35.7	. . .	+4 46 16.5	55 45 57.8	+4 29 23.1	−507.1	923.4	. .
177	Pl. Maia, 20 *c*, E.	1727,	16 0 38	15 51 17	56 9 10.5	56 8 12.7	+4 22 40.8	+918.7	927.5	. .
		Sept. 6	3 3 18.7	. . .	+4 46 47.5	55 52 54.0	+4 21 41.9	+ 58.9	917.9	. .
178	*α* Tauri, I. . .	1738,	9 44 42	9 35 21	66 0 50.9	65 53 42.1	−5 34 18.2	−857.2	903.4	282.5
		Jan. 2	4 33 51.4	. . .	−5 5 36.1	66 7 59.3	−5 29 10.4	−307.8	907.1	143.6
179	*α* Tauri, E. . .	1738,	11 5 57	10 56 36	66 41 44.9	66 22 36.9	−5 32 41.3	+877.6	903.2	. .
		Jan. 2	5 55 19.8	. . .	−5 5 15.5	66 7 59.3	−5 29 10.4	−210.9	898.5	. .
180	*α* Tauri, I. . .	1738,	5 33 53	5 24 32	65 27 45.8	65 54 44.5	−5 24 22.3	−845.3	889.6	272.1
		Dec. 23	23 41 58.3	. . .	−4 43 45.5	66 8 49.8	−5 29 09.8	+287.5	889.3	154.0
181	*α* Tauri, E. . .	1738,	6 33 54	6 24 33	65 57 27.1	66 20 43.7	−5 20 15.1	+713.9	891.6	. .
		Dec. 23	0 42 9.2	. . .	−4 42 41.3	66 8 49.8	−5 29 10.0	+ 534.9	889.5	. .
182	*o* Tauri . . .	1739,	7 0 10	6 50 49	59 16 41.4	59 2 40.0	−5 29 58.5	.	. .	327.0
		Feb. 15	4 41 23.5	. . .	−5 1 7.4	. . .	. . .	. .	. .	111.9
					DELISLE AT LUXEMBOURG.					
183	*τ* Tauri, I. . .	1713,	11 58 24.3	11 49 3.3	68 5 59.0	67 59 16.1	+0 29 10.8	−643.4	939.0	249.4
		Dec. 1	4 41 1.5	. . .	+0 53 38.8	68 9 59.5	+0 40 45.7	−694.9	946.8	178.8
184	B. A. C. 1373, I.	1714,	9 16 0.2	9 6 39.2	65 15 35.8	64 33 0.2	+0 3 0.7	−555.3	947.5	359.7
		Mar. 20	9 7 55.2	. . .	+0 32 12.3	64 42 15.5	−0 9 54.6	+775.3	953.6	65
185	*o* Tauri, I. . .	1714,	10 25 28.9	10 16 7.9	78 55 25.6	78 15 54.9	−1 13 24.4	−864.5	931.2	0.7
		Mar. 21	10 21 31.9	. . .	−0 40 13.7	78 30 19.4	−1 19 41.4	+377.0	943.5	77.8
186	*ξ* Sagittarii, I. .	1714,	15 26 41.6	15 17 20.6	278 55 14.8	279 12 36.7	+1 35 55.7	−903.3	953.4	16.5
		Apr. 6	16 26 39.0	. . .	+2 29 27.0	279 27 40.0	+1 41 53.7	−358.0	971.4	262′
187	*ξ* Sagittarii, E. .	1714,	16 39 56.3	16 30 35.3	279 36 36.7	279 42 52.2	+1 38 3.6	+912.2	955.3	. .
		Apr. 6	17 40 5.8	. . .	+2 32 40.6	279 27 40.0	+1 41 53.7	−230.1	940.4	. .
188	*ω*² Tauri, E. . .	1714,	9 10 0.7	9 0 39.7	61 49 47.1	62 19 5.6	−0 54 23.9	+841.8	965.4	184.2
		Sept. 27	21 34 56.8	. . .	−0 4 38.7	62 5 3.8	−0 46 57.9	−446.0	952.5	237.9
189	*α* Cancri, E. . .	1714,	14 47 21.3	14 38 0.3	129 8 31.3	129 52 43.4	−5 12 53.9	+800.3	899.7	189.1
		Oct. 2	3 32 55.6	. . .	−4 45 8.6	129 39 23.1	−5 6 9.6	−404.3	893.6	300.6
190	*α* Tauri, I. . .	1717,	9 3 4.3	8 53 44.0	65 5 42.7	65 34 48.7	−5 27 16.2	−964.2	953.4	182.5
		Sept. 25	21 21 10.9	. . .	−4 36 58.2	65 50 52.9	−5 29 12.6	+116.4	966.9	243.3
191	*α* Tauri, E. . .	1717,	9 55 23.0	9 46 2.7	65 35 38.3	66 6 28.5	−5 26 27.3	+935.6	956.0	. .
		Sept. 25	22 13 38.2	. . .	−4 38 18.5	65 50 52.9	−5 29 12.6	+165.3	946.0	. .
192	*λ* Geminorum, I.	1718,	13 33 55.0	13 24 34.7	105 0 55.2	104 42 27.3	−5 25 9.9	−524.7	1014.1	295.2
		Jan. 15	9 14 20.3	. . .	−4 49 15.7	104 51 12.0	−5 39 54.6	+884.7	1028.0	169.6

Tabular Exhibit of Reduction of the Occultations—Continued.

DELISLE AT LUXEMBOURG—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	$\odot$ $L-\odot$
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
193	α Tauri, I. . .	1718,	6 31 35.	6 22 15.1	65 35 41.5	65 35 6.5	−5 25 41.1	−961.4	965.9	320.6
		Feb. 9	3 49 25.2	. . .	−4 53 48.7	65 51 7.9	−5 29 16.2	+215.1	981.2	105.3
194	B. A. C. 8184, I.	1718,	8 42 37.2	8 33 16.9	347 0 18.3	347 8 31.9	−0 55 5.3	−528.7	888.7	166.6
		Sept. 9	19 56 38.3	. . .	−0 5 15.3	347 17 20.6	−1 7 6.4	+721.1	894.1	180.7
195	α Tauri, I. . .	1719,	7 42 53.8	7 33 33.5	66 20 35.5	65 38 19.2	−5 36 44.4	−806.6	910.3	31.9
		Apr. 22	9 43 19.9	. . .	−5 5 1.1	65 51 45.8	−5 29 15.1	−449.3	920.2	34.0
196	α Tauri, E. . .	1719,	8 32 35.4	8 23 15.1	66 46 25.9	66 3 31.1	−5 38 47.1	+705.3	908.6	. .
		Apr. 22	10 33 39.8	. . .	−5 4 57.6	65 51 45.8	−5 29 15.1	−572.0	905.4	. .
197	γ Libræ, I. . .	1719,	7 43 32.1	7 34 11.8	231 6 8.6	230 57 14.1	+4 20 39.8	−948.5	970.7	148.0
		Aug. 21	17 41 31.6	. . .	+5 15 17.0	231 13 2.6	+4 24 59.7	−259.9	980.8	83.2
198	α Tauri, I. . .	1719,	8 46 49.1	8 37 28.8	65 12 52.6	65 40 52.6	−5 38 19.0	−714.3	897.8	216.7
		Oct. 30	23 20 57.8	. . .	−4 56 10.8	65 52 46.9	−5 29 12.9	−546.1	896.5	209.2
199	α Tauri, E. . .	1719,	9 43 24.1	9 34 3.8	65 41 27.0	66 6 42.5	−5 35 2.8	+835.6	900.0	. .
		Oct. 30	0 17 42.1	. . .	−4 55 42.9	65 52 46.9	−5 29 12.9	−349.9	902.4	. . .
200	A¹ Tauri, I. . .	1725,	12 25 33.2	12 16 12.9	60 8 2.9	59 20 55.2	+1 9 51.6	−951.0	969.4	331.5
		Feb. 19	10 24 58.7	. . .	+1 44 5.5	59 36 46.2	+1 13 59.4	−247.8	982.4	88.1

DELISLE AT ST. PETERSBURG.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	$\odot$ $L-\odot$
201	9 Tauri, I. . .	1727,	8 54 1.8	6 52 48.3	53 56 31.8	53 22 13.0	+3 40 29.4	−940.0	936.0	339.0
		Feb. 27	7 22 12.1	. . .	+4 12 43.8	53 37 53.0	+3 41 39.7	− 70.3	940.7	74.6
202	Pl. Elec., 17 *b*, I.	1729,	16 35 57.9	14 34 44.4	56 1 25.8	55 24 28.3	+4 13 28.1	−866.1	888.8	252.0
		Dec. 3	9 27 24.9	. . .	+4 48 14.2	55 38 54.4	+4 9 44.1	+224.0	892.4	163.6
203	Pl. Cel., 16 *g*, I.	1729,	16 41 39.6	14 40 26.1	56 4 15.3	55 27 15.0	+4 13 7.6	−782.3	888.6	. .
		Dec. 3	9 33 7.5	. . .	+4 48 9.1	55 40 17.3	+4 20 15.2	−427.6	889.6	163.7
204	Pl. Maia, 20 *c*, I.	1729,	17 16 56.6	15 15 43.1	56 21 45.5	55 44 48.7	+4 10 56.0	−611.2	887.6	252.0
		Dec. 3	10 8 30.3	. . .	+4 47 38.9	55 54 59.9	+4 21 44.6	−648.6	890.0	163.9
205	Pl. Mer., 23 *d*, I.	1729,	17 31 47.4	15 30 33.9	56 29 6.9	55 52 22.6	+4 9 58.5	−225.2	887.2	. .
		Dec. 3	10 23 23.6	. . .	+4 47 26.0	55 56 7.8	+3 55 41.2	+857.3	886.2	. .
206	Pl. Alcy., η, I. .	1729,	17 48 13.8	15 47 0.3	56 37 16.5	56 0 52.7	+4 8 53.6	−770.1	886.8	252.0
		Dec. 3	10 39 52.7	. . .	+4 47 11.7	56 13 42.8	+4 1 23.6	+450.0	890.3	164.2
207	Pl. Pleio., 28 *h*, I.	1729,	18 32 17.4	16 31 3.9	56 59 8.0	56 24 16.1	+4 5 54.9	−759.8	885.6	. .
		Dec. 3	11 24 3.5	. . .	+4 46 32.7	56 36 55.9	+3 58 11.5	+463.4	888.4	. .
208	Pl. Atlas, 27 *f*, I.	1729,	18 37 35.6	16 36 22.1	57 1 45.3	56 27 8.5	+4 5 33.1	−503.0	885.5	252.0
		Dec. 3	11 29 22.6	. . .	+4 46 28.0	56 35 31.5	+3 53 22.7	+730.4	886.2	164.6
209	ν Geminorum, I.	1733,	7 33 8.8	5 31 55.3	92 58 9.1	92 48 44.7	−3 8 12.4	−962.1	959.2	2.5
		Mar. 22	7 33 55.6	. . .	−2 30 39.3	93 4 46.8	−3 5 22.4	−170.0	975.7	90.6

Tabular Exhibit of Reduction of the Occultations—Continued.

DELISLE AT ST. PETERSBURG—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ / $b'-B$	S / D	⊙ / $L-$⊙
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
210	κ Cancri, I.	1733,	7 27 49.6	5 26 36.1	131 59 57.7	132 19 49.8	−5 21 52.2	−436.7	940.8	5.4
		Mar. 25	7 40 25.5	. . .	−4 44 16.9	132 27 6.5	−5 35 30.1	+817.9	926.2	126
211	α Tauri, I.	1736,	10 19 54.3	8 18 40.8	66 28 28.0	65 54 2.8	−5 19 5.0	−718.0	929.9	25.3
		Apr. 14	11 52 54.3	. . .	−4 34 4.4	66 6 0.8	−5 29 11.0	+606.0	937.1	40.8
212	α Tauri, I.	1736,	18 16 12.2	16 14 58.7	65 47 53.8	65 50 44.7	−5 26 4.0	−937.3	944.3	130.0
		Aug. 1	3 0 15.0	. . .	−4 45 7.2	66 6 22.0	−5 29 7.9	+183.9	951.0	296.1
213*	α Tauri, E.	1736,	19 27 50.9	17 26 37.4	66 27 12.6	66 21 51.0	−5 25 29.5	+929.0	945.5	. .
		Aug. 1	4 12 5.5	. . .	−4 46 27.7	66 6 22.0	−5 29 7.9	+218.4	950.2	. .
214	α Tauri, I.	1736,	14 44 52.4	12 43 38.9	66 1 50.4	65 51 26.5	−5 28 59.3	−932.5	923.0	209.9
		Oct. 22	4 51 38.1	. . .	−4 51 35.1	66 6 59.0	−5 29 8.4	+ 9.1	928.3	216.2
215*	α Tauri, E.	1736,	15 59 43.4	13 58 29.9	66 41 17.0	66 22 29.9	−5 29 32.4	+930.9	922.7	. .
		Oct. 22	6 6 41.4	. . .	−4 52 50.2	66 6 59.0	−5 29 8.4	− 24.0	927.0	. .
216	ξ Leonis, I.	1737,	9 41 20.8	7 40 7.3	137 52 4.6	137 43 46.8	−3 14 42.9	−927.7	959.7	47.5
		May 7	12 43 57.9	. . .	−2 24 48.7	137 59 14.5	−3 10 0.6	−282.3	968.3	90.5
217	Jupiter	1737,	15 56 26.8	13 55 13.3	349 23 4.0	349 23 34.7	−1 16 6.0	. .	892.7	61.9
		May 22	19 59 13.8	. . .	−0 23 23.4	. . .	. . .	. .	. . .	. .
218	θ^1 Tauri, I.	1737,	13 3 21.9	11 2 8.4	63 48 15.7	64 5 45.9	−6 0 35.8	−677.7	903.0	120.2
		July 22	21 6 10.4	. . .	−5 8 39.6	64 17 3.6	−5 46 27.0	−848.8	1084	304.1
219	θ^1 Tauri, E.	1737,	13 35 46.1	11 34 32.6	64 4 54.3	64 23 30.4	−5 59 54.7	+386.8	903.9	. .
		July 22	21 38 39.9	. . .	−5 8 48.6	64 17 3.6	−5 46 27.0	−807.7	894.7	. .
220	θ^2 Tauri, E.	1737,	13 48 22.3	11 47 8.8	64 11 22.6	64 30 16.2	−5 59 36.5	+783.8	904.3	. .
		July 22	21 51 18.2	. . .	−5 8 52.1	64 17 12.4	−5 52 4.7	−451.8	901.1	. .
221	71 Tauri, I.	1738,	6 20 4.0	4 18 50.5	63 21 44.4	63 33 34.8	−5 49 41.7	−531.7	898.6	282.5
		Jan. 2	1 8 21.3	. . .	−5 6 30.8	63 42 26.5	−6 1 45.8	+724.1	896.7	141
222	θ^1 Tauri, I.	1738,	7 29 38.5	5 28 25.0	63 56 39.1	64 2 31.6	−5 47 3.0	−909.2	900.0	. .
		Jan. 2	2 18 7.3	. . .	−5 6 23.5	64 17 40.8	−5 46 29.8	− 33.2	905.2	. .
223	θ^2 Tauri, I.	1738,	7 32 54.5	5 31 41.0	63 58 17.7	64 3 50.7	−5 46 55.9	−852.2	900.1	. .
		Jan. 2	2 21 23.8	. . .	−5 6 23.0	64 18 2.9	−5 52 7.6	+311.7	903.3	. .
224	B. A. C. 1391, I.	1738,	8 51 3.5	6 49 50.0	64 37 35.2	64 34 55.8	−5 44 21.0	−801.7	901.1	. .
		Jan. 2	3 39 45.6	. . .	−5 6 9.7	64 48 17.5	−5 37 7.1	−433.9	908.2	. .
225	α Tauri, I.	1738,	12 23 37.8	10 22 24.3	66 24 30.5	65 59 16.2	−5 41 30.2	−523.0	900.1	282.5
		Jan. 2	7 12 54.9	. . .	−5 5 25.2	66 7 59.2	−5 29 10.5	−739.7	904.5	143.6
226	α Tauri, E.	1738,	13 3 17.8	11 2 4.3	66 44 30.5	66 16 7.8	−5 41 45.7	+488.6	899.4	. .
		Jan. 2	7 52 41.4	. . .	−5 5 14.0	66 7 59.2	−5 29 10.5	−755.2	898.2	. .

*By reference to the original notes, it will be seen that the observer was dubious whether both emersions were not too late. The results strongly indicating it, both must be rejected.

Tabular Exhibit of Reduction of the Occultations—Continued.

DELISLE AT ST. PETERSBURG—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ $b'-B$	S' D	⊙ $L-$⊙
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
227	*f* Geminorum, I.	1738,	8 9 48.5	6 8 35.0	109 32 40.8	109 54 37.4	−4 0 25.7	−415.9	930.2	314.0
		Feb. 2	5 0 37.1	. . .	−3 24 10.2	110 1 33.3	−3 46 28.2	−837.5	934.6	156.0
228	71 Tauri, I. . .	1738,	15 3 10.0	13 1 56.5	63 14 4.8	63 29 33.3	−5 54 24.5	−781.2	893.2	. .
		Aug. 8	0 12 22.3	. . .	−5 9 17.0	63 42 34.5	−6 1 48.9	+444.4	895.1	. .
229	71 Tauri, E. . .	1738,	15 59 5.9	13 57 52.4	63 41 45.1	63 53 44.5	−5 51 43.7	+670.0	894.6	. .
		Aug. 8	1 8 27.3	. . .	−5 8 43.9	63 42 34.5	−6 1 48.9	+605.2	895.1	. .
230	θ^1 Tauri, I. . .	1738,	16 21 50.7	14 20 37.2	63 53 0.3	64 3 13.5	−5 50 37.7	−874.8	895.0	136 2
		Aug. 8	1 31 15.9	. . .	−5 8 29.1	64 17 48.3	−5 46 26.3	−251.4	905.9	288.1
231	θ^2 Tauri, I. . .	1738,	16 22 7.7	14 20 54.2	63 53 8.6	64 3 20.4	−5 50 37.0	−890.0	895.0	. .
		Aug. 8	1 31 32.9	. . .	−5 8 29.0	64 18 10.4	−5 52 4.1	+ 87.1	889.6	. .
232	α Tauri, I. . .	1738,	21 18 5.4	19 16 51.9	66 19 34.9	65 58 46.4	−5 40 50.3	−559.6	895.7	136.2
		Aug. 8	6 28 19.3	. . .	−5 5 7.4	66 8 6.0	−5 29 7.4	−702.9	396.8	289.9
233	α Tauri, E. . .	1738,	22 7 49.3	20 6 35.8	66 44 11.4	66 18 49.8	−5 40 26.0	+643.8	894.9	. .
		Aug. 8	7 18 11.3	. . .	−5 4 29.8	66 8 6.0	−5 29 7.4	−678.6	933.7	. .
234	α Tauri, I. . .	1738,	11 57 37.2	9 56 23.7	65 41 42.6	65 56 41.5	−5 38 13.2	−710.1	894.3	189.6
		Oct. 2	0 43 9.6	. . .	−4 54 25.3	66 8 31.6	−5 29 7.5	−545.7	892.9	236.5
235	α Tauri, E. . .	1738,	12 57 57.8	10 56 44.3	66 11 38.5	66 22 16.7	−5 35 11.1	+825.1	895.5	. .
		Oct. 2	1 43 40.0	. . .	−4 53 39.3	66 8 31.6	−5 29 7.5	−363.6	898.2	. .
236	85 Geminorum, I.	1739,	13 40 53.4	11 39 39.9	112 41 42.4	113 10 53.3	−0 58 55.8	−856.5	895.3	210.2
		Oct. 23	3 48 33.1	. . .	−0 24 38.1	113 25 9.8	−0 54 24.6	−271.2	898.3	263.2
237	85 Geminorum, E.	1739,	14 51 33.8	12 50 20.3	113 16 26.1	113 40 6.7	−0 54 33.5	+896.9	896.8	. .
		Oct. 23	4 59 25.2	. . .	−0 21 34.3	113 25 9.8	−0 54 24.6	− 8.9	896.8	. .
238	δ Cancri, I. . .	1739,	13 10 56.5	11 9 43.0	124 14 36.1	124 50 28.8	+0 2 2.3	−882.9	893.5	211.2
		Oct. 24	3 22 27.8	. . .	+0 36 32.6	125 5 11.7	+0 4 8.3	−126.0	891.8	273.9
239	δ Cancri, E. . .	1739,	14 17 18.4	12 16 4.9	124 47 15.2	125 19 58.0	+0 6 33.7	+886.3	895.4	. .
		Oct. 24	4 29 0.6	. . .	+0 39 24.6	125 5 11.7	+0 4 8.3	+145.4	898.2	. .
240	Pl. Elec., 17 *b*, I.	1746,	8 20 40.0	6 19 26.5	56 12 58.4	55 37 4.7	+4 8 6.8	−894.7	896.7	6.2
		Mar. 26	8 36 46.1	. . .	+4 41 2.6	55 51 59.4	+4 9 50.7	−103.9	898.4	49.7
241	Pl. Cel., 16 *g*, I.	1746,	8 38 7.0	6 36 53.5	56 21 14.9	55 45 16.0	+4 7 48.2	−487.3	896.3	. .
		Mar 26	8 54 15.9	. . .	+4 41 24.7	55 53 23.3	+4 20 22.0	−753.8	896.9	. .
242	Pl. Mer., 23 *d*, I.	1746,	9 7 51.3	7 6 37.8	56 36 34.2	55 59 33.3	+4 7 9.0	−580.5	895.7	. .
		Mar. 26	9 24 5.1	. . .	+4 42 2.0	56 9 13.8	+3 55 48.0	+681.0	893.9	. .
243	*p*, I. .	1746,	9 30 38.3	7 29 24.8	56 47 57.8	56 10 47.3	+4 6 34.1	−863.1	895.1	. .
		Mar. 26	9 46 55.9	. . .	+4 42 30.5	56 25 10.4	+4 2 32.3	+241.8	894.3	. .
244	Pl. Alcyone, η, I.	1746,	9 34 36.6	7 33 23.1	56 49 57.0	56 12 46.3	+4 6 27.6	−847.8	895.0	. .
		Mar. 26	9 50 54.8	. . .	+4 42 35.4	56 26 54.1	+4 1 30.7	+296.9	896.3	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

DELISLE AT ST. PETERSBURG—Continued.

No.	Star occulted.	Date.	Local mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Apparent Position of Moon and Star. Latitudes.	$l'-L$ / $b'-B$	S / D	⊙ / $L-$⊙
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
245	Pl. Pleio., 28 *h*, I.	1746,	10 21 25.6	8 20 12.1	57 13 22.5	56 36 44.4	+4 5 3.9	−797.6	893.9	. .
		Mar. 26	10 37 51.5	. . .	+4 43 33.2	56 50 2.0	+3 58 18.2	+405.7	892.6	. .
246	Pl. Bessel 8, I. .	1746,	9 1 43.7	7 0 30.2	56 33 30.3	55 56 34.6	+4 7 17.9	−877.7	895.8	. .
		Mar. 26	9 17 56.5	. . .	+4 41 54.4	56 11 12.3	+4 10 31.3	−193.4	896.5	. .
247	Pl. Bessel 9, I. .	1746,	9 2 28.4	7 1 14.9	56 33 52.6	55 56 56.3	+4 7 16.7	−882.2	895.8	. .
		Mar. 26	9 18 41.3	. . .	+4 41 55.3	56 11 38.5	+4 10 6.0	−169.3	896.0	. .
248	Pl. Bessel 4, I. .	1746,	9 5 18.7	7 4 5.2	56 35 17.8	55 58 19.0	+4 7 12.7	−404.8	895.7	. .
		Mar. 26	9 21 32.1	. . .	+4 41 58.8	56 5 3.8	+4 20 33.1	−800.4	896.5	. .
249	Pl. Bessel 10, I.	1746,	9 11 40.8	7 10 27.3	56 38 28.9	56 1 25.4	+4 7 3.7	−815.6	895.5	. .
		Mar. 26	9 27 55.2	. . .	+4 42 6.8	56 15 1.0	+4 13 20.9	−377.2	896.6	. .
250	Pl. Bessel 15, I.	1746,	9 28 28.7	7 27 15.2	56 46 53.0	56 9 42.8	+4 6 37.7	−877.5	895.1	. .
		Mar. 26	9 44 45.9	. . .	+4 42 27.8	56 24 20.3	+4 3 27.8	+189.9	895.7	. .
251	Pl. Bessel 18, I.	1746,	9 29 44.4	7 28 30.9	56 47 30.9	56 10 20.6	+4 6 35.6	−885.5	895.1	. .
		Mar. 26	9 46 1.8	. . .	+4 42 29.4	56 25 6.1	+4 3 57.5	+158.1	897.3	. .
252	Pl. Bessel 29, I.	1746,	10 9 20.1	8 8 6.6	57 7 19.4	56 30 26.8	+4 5 26.8	−787.8	894.2	. .
		Mar. 26	10 25 44.0	. . .	+4 43 18.3	56 43 34.6	+4 12 32.1	−425.3	893.5	. .
253	Pl. Cel., 16 *g*, I.	1747,	13 1 48.5	11 0 35.0	56 23 11.7	55 46 42.0	+4 33 5.9	−464.3	892.5	300.6
		Jan. 20	9 1 27.7	. . .	+5 6 42.3	55 54 26.3	+4 20 22.6	+763.3	892.7	115.3
254	Pl. Tay., 19 *e*, I.	1747,	13 3 55.5	11 2 42.0	56 24 14.6	55 47 42.2	+4 33 1.5	−870.5	892.5	. .
		Jan. 20	9 3 35.1	. . .	+5 6 43.3	56 2 12.7	+4 29 33.1	+208.4	892.5	. .
255	Pl. Ast., 21 *k*, I.	1747,	13 25 4.4	11 23 50.9	56 34 43.3	55 57 49.2	+4 32 14.8	−894.4	888.6	. .
		Jan. 20	9 24 47.4	. . .	+5 6 52.6	56 12 43.6	+4 32 32.2	− 17.4	891.8	. .
256	Pl. Maia, 20 *c*, I.	1747,	13 26 21.5	11 25 8.0	56 35 21.5	55 58 26.5	+4 32 11.9	−642.4	888.6	. .
		Jan. 20	9 26 4.7	. . .	+5 6 53.1	56 9 9.0	+4 21 51.8	+620.1	891.5	. .
257	22 *l*, I.	1747,	13 28 21.5	11 27 8.0	56 36 20.9	55 59 24.5	+4 32 7.2	−890.4	891.8	. .
		Jan. 20	9 28 5.1	. . .	+5 6 54.0	56 14 14.9	+4 30 33.1	+ 94.1	892.6	. .
258	Pl. Tay., 19 *e*, E.	1747,	13 15 12.5	11 13 59.0	56 0 54.0	56 17 10.9	+4 27 30.7	+887.1	892.5	127.4
		July 30	21 47 56.1	. . .	+5 14 49.9	56 2 23.8	+4 29 30.3	−119.6	892.5	288.6
259	Pl. Bessel 4, E. .	1747,	13 19 33.5	11 18 20.0	56 3 3.3	56 19 21.4	+4 27 43.4	+783.5	892.6	. .
		July 30	21 52 17.8	. . .	+5 14 49.9	56 6 17.9	+4 20 30.9	+432.5	892.9	. .
260	Pl. Maia, 20 *c*, E.	1747,	13 26 37.5	11 25 24.0	56 6 33.4	56 22 52.2	+4 28 4.5	+812.2	892.8	. .
		July 30	21 59 23.0	. . .	+5 14 50.0	56 9 20.0	+4 21 49.1	+375.4	892.6	. .

Tabular Exhibit of Reduction of the Occultations—Continued.

FLAMSTEED AT GREENWICH.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Latitudes.	$l'-L$ / $b'-B$	S' / D	⊙ / $L-⊙$
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
261	ζ Arietis, I. . .	1676,	7 16 29	. . .	47 50 0.7	47 11 24.2	+2 45 29.8	− 845.1	892.8	358.7
		Mar. 18	7 4 57.6	. . .	+3 9 51.1	47 25 29.3	+2 51 45.7	− 375.9	924.0	48.7
262	28 (g) Gem., I. .	1676,	13 17 30	. . .	110 50 41.7	110 22 10.7	−2 50 21.1	− 752.9	919.3	3.7
		Mar. 23	13 26 40.7	. . .	−2 4 28.7	110 34 43.6	−2 40 44.5	− 576.6	947.6	106.9
263	κ Aquarii, E. .	1676,	11 30 10	. . .	334 57 33.0	335 10 54.0	+4 6 47.5	+ 952.6	942.4	98.5
		June 29	18 5 25.5	. . .	+5 1 25.5	334 55 1.4	+4 7 45.0	− 57.5	951.9	236.4
264	ο Sagittarii, I. .	1676,	8 16 45	. . .	280 13 24.6	280 14 10.2	+0 45 54.0	− 875.1	974.8	147.3
		Aug. 19	18 12 33.0	. . .	+1 42 46.2	280 28 45.3	+0 56 22.9	− 628.9	1078.4	133.2
265	Mars, I. . . .	1676,	12 17 23	. .	77 25 29.8	77 55 41.3	−0 32 56.6	− 799.1	892.6	158.8
		Aug. 31	23 1 9.2	. . .	+0 9 26.0	78 9 0.4	−0 28 0.4	− 296.2	852.2	279.4
266	Mars, E. . . .	1676,	13 18 10	. . .	77 55 28.0	78 25 14.5	−0 32 7.6	+ 886.8	894.9	. .
		Aug. 31	0 2 6.2	. . .	+0 6 46.4	78 10 27.7	−0 27 57.6	− 250.0	921.3	. .
267	π Sagittarii, I. .	1676,	5 40 55	. . .	281 53 32.9	281 28 45.2	+1 35 29.5	− 938.0	985.5	227.9
		Nov. 9	20 59 35	. . .	+2 28 36.6	281 44 23.2	+1 28 47.9	+ 401.6	1020.0	53.8
268	Not identified .	1677,	12 17 7	. . .	64 39 50.8	64 0 16.9	−0 20 41.4	. .	893.9	349.5
		Mar. 9	11 29 58.8	. . .	+0 16 32.4	. . .	. . .	. .	. . .	. .
269	ρ^2 Sagittarii, I. .	1678,	7 6 32	. . .	284 49 30.4	284 40 21.8	+3 53 35.7	− 953.3	969.2	181.8
		Sept. 24	19 22 10.0	. . .	+4 48 9.2	284 56 15.1	+3 48 36.1	+ 299.6	997.2	103.1
270	Not identified .	1678,	8 28 20	. . .	. . .	. . .	. . .	. . .	. .	216.4
		Oct. 29	. . .	. . .	. . .	. . .	. . .	. .	. . .	. .
271	Lalande 4903 .	1678,	8 35 38	. . .	37 3 53.8	37 17 2.7	−0 47 5.6	. .	980.7	. .
		Oct. 29	23 9 30.1	. . .	−0 0 59.9	. . .	. . .	. .	. . .	. .
272	α Cancri, I. . .	1680,	9 1 24	. . .	128 15 55.5	128 55 21.3	−5 1 19.4	− 929.2	939.3	296.8
		Jan. 16	4 45 50.8	. . .	−4 31 28.3	129 10 50.5	−5 6 20.1	+ 300.7	973.2	192.4
273	α Cancri, E. . .	1680,	10 7 5	. . .	128 52 5.1	129 25 4.0	−4 59 48.9	+ 853.5	940.8	. .
		Jan. 16	5 51 42.6	. . .	−4 30 4.9	129 10 50.5	−5 6 20.1	+ 391.2	935.9	. .
274	α Tauri, I. . .	1680,	15 0 53	. . .	64 54 25.7	65 3 44.4	−5 24 3.8	− 964.2	986.3	172.2
		Sept. 13	2 36 28.7	. . .	−4 46 29.7	65 19 48.6	−5 29 22.1	+ 318.3	1011.2	253.1
275	α Tauri, E. . .	1680,	16 9 12	. . .	65 35 10.8	65 34 37.4	−5 22 56.6	+ 888.8	986.8	. .
		Sept. 13	3 44 58.9	. . .	−4 48 6.0	65 19 48.6	−5 29 22.1	+ 385.5	965.1	. .
276	α Tauri, I. . .	1680,	7 50 43	. . .	64 33 16.0	65 2 37.8	−5 29 14.3	−1051.6	1008.9	226.3
		Nov. 7	23 1 58.6	. . .	−4 39 27.6	65 20 9.4	−5 29 23.2	+ 8.9	1046.8	198.8
277	α Tauri, E. . .	1680,	8 47 12	. . .	65 9 12.5	65 36 22.2	−5 27 36.5	+ 972.8	1011.2	. .
		Nov. 7	23 58 36.9	. . .	−4 40 47.7	65 20 9.4	−5 29 23.2	+ 106.7	974.8	. .
278	γ Tauri, I. . .	1682,	9 45 35	. . .	61 48 36.0	61 5 4.0	−5 49 6.8	− 979.8	957.7	354.8
		Mar. 14	9 16 54.8	. . .	−5 14 55.9	61 21 23.8	−5 46 4.3	− 182.5	991.7	66.6

Tabular Exhibit of Reduction of the Occultations—Concluded.

FLAMSTEED AT GREENWICH—Continued.

No.	Star occulted.	Date.	Local Mean and Sidereal Times.	Greenwich Mean Time.	Moon's Tabular Geocentric Position.	Apparent Position of Moon and Star. Longitudes.	Latitudes.	$l'-L$ $b'-B$	S' D	$\odot$ $L-\odot$
			h m s	h m s	° ′ ″	° ′ ″	° ′ ″	″	″	°
279	γ Tauri, E. . .	1682, Mar. 14	10 41 15 10 12 43.9	. . . . . .	62 20 28.8 −5 14 56.7	61 35 0.3 61 21 23.8	−5 51 15.5 −5 46 4.3	+876.5 −311.2	955.7 925.9	354.8 66.6
280	γ Tauri, I. . .	1683, Feb. 5	11 57 41 9 2 32.7	. . . . . .	61 51 25.1 −5 3 33.0	61 9 11.8 61 22 22.1	−5 36 41.8 −5 46 4.1	−790.8 +562.3	943.7 967.1	317.4 104.0
281	γ Tauri, E. . .	1683, Feb. 5	12 47 43 9 52 42.9	. . . . . .	62 19 7.1 −5 2 46.4	61 35 28.5 61 22 22.1	−5 37 42.4 −5 46 4.1	+786.4 +501.7	942.3 929.6	. . . .
282	119 Tauri, I. . .	1683, Apr. 2	8 46 40 9 31 47.4	. . . . . .	79 18 19.3 −4 3 42.6	78 43 0.3 78 58 17.0	−4 38 22.9 −4 43 38.6	−916.7 +315.7	942.4 966.6	13.3 65.7
283	119 Tauri, E. . .	1683, Apr. 2	9 27 54 10 13 8.2	. . . . . .	79 40 58.4 −4 2 29.5	79 3 26.6 78 58 17.0	−4 38 55.4 −4 43 38.6	+909.6 +283.2	941.2 949.8	. . . .
284	α Leonis, I. . .	1683, May 4	9 55 24 12 46 52.4	. . . . . .	145 25 17.6 +1 24 1.1	145 14 4.0 145 25 51.2	+0 39 1.9 +0 27 16.6	−707.2 +705.3	981.8 998.7	44.6 100.8
285	α Leonis, E. . .	1683, May 4	10 40 56 13 32 31.9	. . . . . .	145 52 10.9 +1 26 17.7	145 37 7.1 145 25 51.2	+0 38 26.0 +0 27 16.6	+675.9 +669.4	980.5 951.3	. . . .
286	Jupiter, I. . .	1686, Apr. 10	9 33 33 . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . .	. . . .	21.4 . .
287	Jupiter, E. . .	1686, Apr. 10	10 32 38 . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . .
288	Saturn . . .	1687, Mar. 28	13 30 37 . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . .	. . . .	8.4 . .

§ 13.

EQUATIONS OF CONDITION GIVEN BY THE PRECEDING OCCULTATIONS OF STARS.

We may consider it useless to attempt to determine from these older observations any elements of the moon's orbit which remain constant, and which, therefore, can be determined for any time from recent observations alone. Such are the moon's eccentricity, inclination, semi-diameter, and parallax. But it may be advisable to introduce the corrections of these last two elements into the equations, in order that when definitive modern values are obtained, the equations may be corrected accordingly. It is otherwise with the longitudes of the node and of the perigee, because the variations of these quantities have to be determined from observations, and the epoch of the observations now under consideration is so much more remote than that of the observations used by HANSEN, that we may expect them to give good results for the values of the variations in question. The most important element to be determined is the correction to the moon's mean longitude, and it is to this that our attention will be principally devoted.

The only elements which we shall attempt to determine at the present time are the corrections to the moon's mean longitude and longitude of the node, these being the only ones the admissible alterations in which can materially alter the conclusions to be drawn from the accounts of ancient eclipses. The correction to HANSEN's motion of the perigee is probably very small, and any value of it which could be deduced at present would be only provisional. We shall therefore present the equations of condition in such a form that they can be hereafter definitively resolved with improved data, when the latter are available.

Errors to which the equations are liable.—These may be divided into two classes; (α) those of pure observation, and (β) those of the elements of reduction.

(α) The errors of pure observation resolve themselves almost entirely into errors in the determination of the time, provided that the instantaneous immersion or emersion of the star is actually observed. In the case of immersions at the dark limb, this can not be a subject of doubt; but in the case of the other three classes of phenomena, more or less doubt or suspicion may exist, according to circumstances. In the case of the brighter stars, such as Aldebaran and Spica, and, indeed, from the year 1680 onward, in the case of all stars brighter than the fourth magnitude, no distinction of bright or dark limb need be made, because such stars can be readily seen at the bright limb with telescopes of moderate optical power. Observations of smaller stars at the bright limb are to be looked on with suspicion, and rejected entirely if there is no special reason to believe them accurate. All emersions are to be received with suspicion, owing to the doubt whether the observer saw the star at the moment of its reappearance. They should be retained only when there is reason to believe that the observer did not record as good an observation which failed in this way.

Besides these errors of observation, there may be a personal error of a fraction of a second in estimating the time, which will necessarily elude discussion, and which, therefore, need not be farther considered.

(β) The errors in the elements may be divided into three classes: (1) those of the lunar theory; (2) those arising from deviations of the moon from a spherical form; (3) those of the adopted position of the occulted star.

(1) In Part III of Papers published by the Transit of Venus Commission, periodic corrections to HANSEN'S Theory are deduced, of which the mean value will somewhat exceed one second. Mr. NEISON has found a term produced by the action of Jupiter, which has a yet larger coefficient. Other terms, still unknown, may hereafter be discovered. Altogether, I think the probable error of HANSEN'S Theory, leaving out terms of long period, may be estimated at $2''$.

(2) I am not aware of any investigation having for its object to determine the deviations of the moon from a spherical figure as affecting the time of an occultation. The probable magnitude of this deviation is, I think, less than $1''$.

(3) The probable errors in the computed positions of the occulted stars may be roughly estimated at $2''$ in the case of stars well observed by BRADLEY, and at a value still greater in the case of stars not so observed.

Leaving out errors of observation, I conceive that the minimum probable error of the computed value of the distance between the star and the centre of the moon (D) can hardly be less than $3''$ in the most favorable cases, and may be greater to any extent in unfavorable ones. When in the course of time the lunar theory is perfected, and the proper motions of the stars are better determined, this probable error may be considerably diminished.

Whenever there was any means of estimating the probable error of the time, that estimate is given in the following list of equations in the column $\pm \varepsilon$. Its effect is to be included in estimating the probable error. To enable this to be done, the change of D in one second of time is included in the equations of condition. The significations of the indeterminate quantities in the equations are as follows:—

$\delta\varepsilon$, the correction to HANSEN'S mean longitude of the moon at the date.

δt, the correction to the observed time, should any be necessary.

$\delta\varpi$, the correction to the longitude of perigee.

$\delta\theta$, the correction to the longitude of node.

δb_0, the correction to the moon's latitude.

$\delta\Pi$, the correction to the moon's parallax.

The mode of computing the coefficients of these quantities has already been described in § 6, pages 55 to 68.

The absolute terms of the equations are the values of $D - S'$, formed from the proper column in the exhibit of reductions already given.

In column $\pm \varepsilon$ is given the supposed probable error of the observed times, or the probable order of magnitude of δt. In the observations of CASSINI, Series II, it may be assumed that the probable error is always about 2^s or 3^s.

The phase (immersion or emersion) and the limb (bright or dark) are indicated only in the unfavorable cases, blank signifying an immersion or a phenomenon at the dark limb, while E indicates an emersion, and B the bright limb.

After the time of HEVELIUS, the probable errors of the equations arise almost entirely from the uncertainties in the positions of the stars and the periodic inequalities of the moon, and are but slightly increased by the probable errors of the observed times. In the case of these observations, the last column shows the relative weights which have been assigned in the provisional solutions of the equations.

BULLIALDUS.

Number.	Equation.	±ε	Year.	Phase.	Limb.
	″	s			
2	$0 = -0.63\delta\varepsilon - 0.23\delta t - 79.1$	.	1635.0	.	.
3	$0 = -0.92 \quad -0.47 \quad +105.6$	.	1639.3	.	.
4	$0 = -0.80 \quad -0.44 \quad +10.7$	.	1641.3	.	.

GASSENDUS.

Number.	Equation.	±ε	Year.	Phase.	Limb.
5	$0 = -0.83\delta\varepsilon - 0.50\delta t + 34.6$	.	1627.5	.	.
6	$0 = -0.91 \quad -0.41 \quad +62.4$	.	1627.7	.	.
7	$0 = -0.59 \quad -0.21 \quad +17.5$	.	1632.1	.	.
8	$0 = +0.28 \quad +0.19 \quad +3.8$	.	"	E	B
*9	$0 = -0.79 \quad -0.27 \quad +156.0$	.	1635.7	.	.
10	$0 = +1.07 \quad -0.58 \quad +109.0$	.	1637.2	.	.
11	$0 = -0.83 \quad -0.42 \quad +57.4$	.	"	.	.
12	$0 = -0.62 \quad -0.39 \quad +41.8$	.	"	.	.
13	$0 = -1.02 \quad -0.60 \quad +86.8$	.	"	.	.
14	$0 = -0.98 \quad -0.38 \quad +47.0$	.	1638.1	.	.
15	$0 = -0.68 \quad -0.27 \quad +6.8$	.	"	.	.
16	$0 = -1.08 \quad -0.54 \quad -50.8$	.	1639.0	.	B

HEVELIUS.

Number.	Equation.	±ε	Year.	Phase.	Limb.
17	$0 = -1.07\delta\varepsilon - 0.47\delta t + 57.3$	35	1644.9	.	B
18	$0 = +1.04 \quad +0.48 \quad -39.6$	35	"	E	.
19	$0 = -1.10 \quad -0.47 \quad +17.5$	35	1645.8	.	B
20	$0 = +1.11 \quad +0.49 \quad -30.9$	35	"	E	.
22	$0 = -0.59 \quad -0.30 \quad +53.5$	25	1658.8	.	B
23	$0 = +0.92 \quad +0.38 \quad -25.0$	12	1660.3	E	.
24	$0 = -0.81 \quad -0.37 \quad +6\ 6$	20	1660.5	.	.
25	$0 = -0.83 \quad -0.45 \quad +38.1$	40	1663.2	.	.
26	$0 = -1.09 \quad -0.58 \quad +105.5$	25	"	.	.
27	$0 = -1.02 \quad -0.56 \quad +53.1$	25	"	.	.
28	$0 = -0.65 \quad -0.27 \quad +11.0$	12	1663.6	.	B
29	$0 = +0.66 \quad +0.26 \quad +3.2$	12	"	E	.

HEVELIUS—Continued.

Number.	Equation.	±ε	Year.	Phase.	Limb.
	″	s			
30	$0 = -1.03\delta\varepsilon - 0.54\delta t + 37.4$	18	1664.2	.	.
31	$0 = +0.97 \quad +0.57 \quad -15.4$	18	"	E	B
35	$0 = -0.86 \quad -0.34 \quad +29.3$	15	1671.3	.	.
36	$0 = +0.71 \quad +0.34 \quad -23.4$	15	"	E	B
37	$0 = -1.00 \quad -0.43 \quad +51.7$	30	1672.8	.	B
38	$0 = -1.14 \quad -0.48 \quad +48.8$	28	"	.	B
39	$0 = -1.00 \quad -0.41 \quad +53.9$	25	"	.	B
40	$0 = -0.69 \quad -0.36 \quad +11.2$	25	1673.2	.	.
41	$0 = -0.77 \quad -0.39 \quad +33.3$	25	"	.	.
42	$0 = -0.89 \quad -0.48 \quad +15.4$	25	"	.	.
43	$0 = -0.81 \quad -0.44 \quad +23.1$	25	"	.	.
44	$0 = -0.96 \quad -0.45 \quad +49.9$	25	1674.6	.	B
45	$0 = -0.27 \quad -0.18 \quad +25.3$	25	"	.	B
46	$0 = -0.78 \quad -0.35 \quad +40.8$	25	"	.	B
47	$0 = +0.37 \quad +0.11 \quad +3.9$	25	"	E	.
48	$0 = -0.18 \quad -0.13 \quad +12.8$	25	"	.	B
49	$0 = +0.90 \quad +0.42 \quad +34.1$	25	"	E	.
50	$0 = -0.91 \quad -0.38 \quad +26.2$	25	"	.	B
51	$0 = -0.36 \quad -0.11 \quad -7.7$	25	"	E	.
52	$0 = +0.55 \quad +0.27 \quad -14.8$	25	"	E	.
53	$0 = +0.79 \quad +0.36 \quad -23.1$	25	"	E	.
55	$0 = -0.57 \quad -0.24 \quad +10.0$	30	1675.0	.	.
57	$0 = +0.52 \quad +0.24 \quad -1.8$	30	"	E	.
58	$0 = -0.88 \quad -0.45 \quad +46.3$	18	1676.7	.	B
59	$0 = +0.90 \quad +0.41 \quad -18.8$	20	"	E	.
62	$0 = -0.88 \quad -0.40 \quad -25.4$	22	1678.2	.	.
63	$0 = -0.88 \quad -0.35 \quad +15.3$	22	1679.2	.	B
64	$0 = -0.91 \quad -0.36 \quad +12.1$	20	"	.	B
65	$0 = +0.86 \quad +0.36 \quad +4.8$	15	"	E	.
66	$0 = +0.89 \quad +0.38 \quad -24.4$	16	"	E	.
69	$0 = -0.56 \quad -0.24 \quad +19.4$	6?	1679.5	.	B
70	$0 = +0.55 \quad +0.22 \quad +11.3$	6?	"	E	.
71	$0 = -1.13 \quad -0.48 \quad +54.6$	20	1681.0	.	.
72	$0 = +1.09 \quad +0.47 \quad -1.5$	17	"	E	B
73	$0 = -1.05 \quad -0.44 \quad +57.4$	8	1683.0	.	.
74	$0 = +1.04 \quad +0.44 \quad -39.3$	8	"	E	B
75	$0 = -1.00 \quad -0.53 \quad +146.5$	25	1683.3	.	.
76	$0 = -0.96 \quad -0.54 \quad +98.1$	22	"	.	.
77	$0 = +0.95 \quad +0.56 \quad -59.6$	20	"	E	B

* The final revision of the observations for time indicate a value of $\delta t = +143^s$.

CASSINI AND OTHERS.

Number.	Equation.							± ε	Year.	Phase.	Limb.	Wt.
							''	s				
78	$0 = -0.90\delta\varepsilon$	$-0.38\delta t$	$-1.93e\delta\varpi$	$0.00i\delta\theta$	$-0.01\delta b_0$	$+0.32\delta\Pi$	$+23.1$	6?	1672.6	.	.	½
80	$0 = -0.82$	-0.38	$+0.91$	$+0.11$	$+0.68$	-0.83	$+31.7$	10?	1676.2	.	B	⅓
81	$0 = +0.97$	$+0.37$	-1.09	$+0.08$	$+0.49$	$+0.13$	-36.6	10?	"	E	.	0
85	$0 = -0.72$	-0.40	$+0.23$	-0.22	$+0.71$	$+0.18$	$+19.5$	2	1683.1	.	.	1
86	$0 = -0.32$	-0.18	-0.45	$+0.94$	-0.95	$+0.37$	$+12.7$	3	1685.0	.	.	1
87	$0 = +0.48$	$+0.16$	$+0.66$	$+0.86$	-0.87	$+0.56$	-7.6	3?	"	E	.	1
88	$0 = -0.76$	-0.39	-1.13	$+0.09$	-0.56	$+0.81$	$+19.5$	5	1686.5	.	.	1
92	$0 = -1.05$	-0.59	$+1.61$	$+0.15$	-0.35	-0.13	$+16.0$	3?	1690.5	.	B	1

LA HIRE.

Number.	Equation.							± ε	Year.	Phase.	Limb.	Wt.
93	$0 = -1.07\delta\varepsilon$	$-0.42\delta t$	$+1.52e\delta\varpi$	$0.00i\delta\theta$	$-0.08\delta b_0$	$+0.28\delta\Pi$	$+34.9$	2	1682.1	.	.	1
94	$0 = -1.04$	-0.41	$+1.47$	0.00	$+0.27$	$+0.10$	$+28.0$	2	"	.	.	1
95	$0 = -0.32$	-0.18	-0.45	$+0.94$	-0.95	$+0.37$	$+12.8$	1	1685.0	.	.	1
96	$0 = +0.48$	$+0.16$	$+0.66$	$+0.86$	-0.87	$+0.56$	-7.9	1	"	E	.	1
97	$0 = -0.90$	-0.50	-2.00	-0.08	$+0.08$	-0.63	$+21.4$	2	1685.8	.	B	1
98	$0 = -0.60$	-0.36	$+0.95$	-0.28	-0.84	$+0.33$	$+17.0$	2	1699.6	.	B	1
99*	$0 = +0.73$	$+0.30$	-1.16	-0.24	-0.74	$+0.85$	-19.0	2	"	E	.	1
100	$0 = -0.57$	-0.22	-0.52	-0.30	$+0.81$	-0.14	$+8.2$	2	1701.7	.	B	1
101	$0 = +0.53$	$+0.21$	$+0.48$	-0.32	$+0.84$	-0.79	-11.4	2	"	E	.	0
104	$0 = -0.60$	-0.24	-1.30	$+0.76$	$+0.76$	-0.83	$+3.2$	2	1718.7	.	.	½

CASSINI, ETC.—SERIES II.

Number.	Equation.							± ε	Year.	Phase.	Limb.	Wt.
105	$0 = -0.75\delta\varepsilon$	$-0.40\delta t$	$+1.16e\delta\varpi$	$-0.21i\delta\theta$	$-0.76\delta b_0$	$+0.99\delta\Pi$	$+22.9$	.	1705.6	.	B	.
106	$0 = -0.95$	-0.43	$+1.60$	$+0.07$	-0.59	$+0.77$	$+23.3$	.	1705.7	.	.	.
107	$0 = +1.01$	$+0.44$	-1.86	$+0.04$	-0.34	-0.23	-20.3	.	"	E	B	.
108	$0 = -0.74$	-0.33	$+0.82$	-0.68	$+0.70$	$+0.19$	-40.0	.	1706.1	.	.	.
109	$0 = -0.83$	-0.31	-0.52	$+0.21$	-0.55	$+0.31$	$+20.8$	.	"	.	.	.
110	$0 = -0.77$	-0.27	-0.97	-0.08	-0.58	$+0.32$	$+21.8$	.	1706.3	.	.	.

These six equations result from using CASSINI's correction to the quadrant, which is probably incorrect. In the following these equations are given as resulting from the new correction.

Number.	Equation.							± ε	Year.	Phase.	Limb.	Wt.
111	$0 = -0.75$	-0.40	$+1.16$	-0.21	-0.76	$+0.99$	$+14.1$	.	1705.6	.	B	1
112	$0 = -0.95$	-0.43	$+1.60$	$+0.07$	-0.59	$+0.77$	$+17.5$	.	1705.7	.	.	1
113	$0 = +1.01$	$+0.44$	-1.86	$+0.04$	-0.34	-0.23	-14.1	.	"	E	B	0
114	$0 = -0.74$	-0.33	$+0.82$	-0.68	$+0.70$	$+0.19$	-46.9	.	1706.1	.	.	0
115	$0 = +0.01$	-0.02	-0.01	-0.98	$+1.01$	-0.39	-12.7	.	"	.	.	0
116	$0 = +0.03$	-0.01	-0.04	-0.98	$+1.01$	-0.41	-13.1	.	"	.	.	0
117	$0 = +0.30$	$+0.11$	-0.33	-0.94	$+0.96$	-0.57	$+15.6$	.	"	E	B	0
118	$0 = -0.82$	-0.30	-0.50	$+0.21$	-0.55	$+0.31$	$+16.4$	.	"	.	.	1
119	$0 = -0.76$	-0.27	-0.95	-0.08	-0.59	$+0.32$	$+15.7$	.	1706.3	.	.	1
120	$0 = +0.49$	$+0.28$	$+0.62$	-0.13	-0.86	$+0.46$	-9.7	.	"	E	B	0
121	$0 = -0.46$	-0.13	-0.98	-0.85	-0.87	$+0.62$	$+7.5$	.	1706.4	.	.	1
122	$0 = -1.05$	-0.43	$+1.81$	-0.41	$+0.41$	$+0.39$	$+17.2$	.	1706.9	.	.	1
123	$0 = -1.05$	-0.56	$+1.84$	$+0.36$	-0.38	$+0.99$	$+9.9$	.	1707.3	.	.	1

* Cassini's record is 10^s earlier than LA HIRE's. I have supposed $\delta t = -7^s$ in solving this equation.

CASSINI, ETC.—SERIES II—Continued.

Number.	Equation.							Year.	Phase.	Limb.	Wt.
							″				
124	$0 = -0.52\delta\varepsilon$	$-0.21\delta t$	$-1.16e\delta\varpi$	$-0.56i\delta\theta$	$-0.82\delta b_0$	$+0.89\delta\Pi$	+ 15.7	1707.7	.	.	$\frac{1}{4}$
125	0 = + 0.56	+ 0.23	+ 1.24	− 0.53	− 0.78	+ 0.59	− 6.8	"	E	B	1
126	0 = − 0.94	− 0.50	+ 0.26	+ 0.38	− 0.38	+ 0.99	+ 13.7	1708.1	.	.	1
127	0 = − 0.93	− 0.50	+ 0.25	+ 0.38	− 0.38	+ 1.00	+ 7.4	"	.	.	
128	0 = + 1.01	+ 0.61	− 1.44	+ 0.12	− 0.27	+ 0.65	+ 84.1	1708.7	E	.	0
129	0 = − 0.83	− 0.39	+ 1.34	+ 0.66	+ 0.66	− 0.74	+ 17.2	1709.3	.	.	1
130	0 = − 0.59	− 0.30	− 1.32	+ 0.75	− 0.76	+ 0.57	+177.2	1709.7	.	.	0
131	0 = − 0.86	− 0.54	− 0.03	+ 0.11	− 0.46	+ 0.05	+ 7.8	"	.	B	$\frac{1}{2}$
132	0 = − 0.30	− 0.22	− 0.01	+ 0.23	− 0.95	+ 0.71	+ 10.6	"	.	B	$\frac{1}{2}$
133	0 = − 0.36	− 0.26	− 0.01	+ 0.22	− 0.93	+ 0.65	+ 17.8	"	.	B	$\frac{1}{2}$
134	0 = + 0.50	+ 0.25	+ 0.01	+ 0.21	− 0.86	+ 0.96	− 4.0	"	E	.	0
135	0 = + 0.93	+ 0.52	+ 0.02	+ 0.07	− 0.29	+ 0.68	− 1.3	"	E	.	0
136	0 = − 0.91	− 0.50	− 1.56	+ 0.03	+ 0.23	− 0.65	+ 10.4	1710.9	.	.	1
137	0 = − 0.40	− 0.26	− 0.67	− 0.14	− 0.91	+ 0.47	+ 13.0	"	.	.	1
138	0 = − 0.05	− 0.08	− 0.08	− 0.16	− 1.00	− 0.77	+ 10.2	"	.	.	1
139	0 = + 0.32	+ 0.11	+ 0.55	− 0.15	− 0.94	+ 0.83	+ 12.1	"	E	B	0
140	0 = + 0.92	+ 0.44	+ 1.56	− 0.03	− 0.17	+ 0.56	+ 13.9	"	E	B	0
141	0 = − 0.79	− 0.31	− 1.76	− 0.21	− 0.50	+ 0.39	+ 17.5	1711.7	.	B	$\frac{1}{2}$
142	0 = − 0.20	− 0.09	− 0.44	− 0.42	− 0.99	+ 0.44	+ 12.6	"	.	B	$\frac{1}{2}$
143	0 = − 0.48	− 0.18	− 1.06	+ 0.38	+ 0.86	− 0.11	+ 8.1	"	.	B	$\frac{1}{2}$
144	0 = + 0.81	+ 0.32	+ 1.80	− 0.20	− 0.46	− 0.20	+ 7.8	"	E	.	0
145	0 = + 0.48	+ 0.19	+ 1.08	+ 0.38	+ 0.85	− 0.60	− 6.3	"	E	.	0
146	0 = − 0.56	− 0.30	+ 0.13	+ 0.39	+ 0.84	− 0.68	+ 11.8	1712.4	.	.	1
147	0 = + 0.66	+ 0.28	− 0.17	+ 0.35	+ 0.77	− 0.85	− 4.1	"	E	B	0
148	0 = − 0.93	− 0.50	− 0.26	+ 0.31	+ 0.32	+ 0.41	+ 12.1	1714.2	.	.	1
149	0 = − 0.98	− 0.40	+ 1.16	+ 0.26	− 0.30	+ 0.06	+ 18.0	1714.3	.	B	1
150	0 = + 0.98	+ 0.39	− 1.17	+ 0.28	− 0.32	+ 0.34	− 14.9	"	E	.	1
151	0 = − 0.87	− 0.33	+ 1.56	+ 0.48	+ 0.60	− 0.46	+ 13.9	1715.6	.	B	1
152	0 = + 0.67	+ 0.32	− 1.19	+ 0.65	+ 0.80	− 0.60	+ 4.2	"	E	.	0
157	0 = − 0.56	− 0.27	+ 0.64	− 0.30	− 0.86	+ 0.77	+ 7.6	"	.	B	1
158	0 = + 0.77	+ 0.27	− 0.89	− 0.25	− 0.72	+ 0.38	− 1.6	"	E	.	0
159	0 = − 0.89	− 0.39	+ 0.89	− 0.23	− 0.58	+ 0.55	+ 4.6	1715.8	.	.	1
160	0 = − 0.92	− 0.45	+ 0.73	− 0.19	− 0.42	+ 0.93	+ 11.4	1716.0	.	.	1
161	0 = − 1.04	− 0.61	+ 1.34	+ 0.04	+ 0.08	− 0.60	+ 17.2	1717.7	.	B	1
162	0 = + 1.02	+ 0.59	− 1.32	+ 0.10	+ 0.22	+ 0.37	− 13.4	"	E	.	1
163	0 = − 0.60	− 0.24	− 1.30	+ 0.76	+ 0.76	− 0.83	+ 5.4	1718.7	.	.	$\frac{1}{2}$
164	0 = − 0.84	− 0.41	− 0.60	+ 0.02	− 0.49	+ 0.95	+ 8.7	1719.3	.	.	1
165	0 = + 0.73	+ 0.44	+ 0.52	+ 0.03	− 0.64	− 0.22	− 7.8	"	E	B	1
166	0 = + 0.85	+ 0.38	+ 1.26	+ 0.08	− 0.41	+ 0.69	− 4.4	1719.8	E	.	0
167	0 = − 0.80	− 0.37	− 1.36	− 0.08	+ 0.52	− 0.80	+ 8.1	1719.9	.	.	1
168	0 = − 0.33	− 0.19	+ 0.49	− 0.60	+ 0.97	− 0.76	− 2.2	1720.3	.	.	0
169	0 = + 0.54	+ 0.19	− 0.80	− 0.55	+ 0.89	− 0.78	− 7.6	"	E	B	0
170	0 = − 0.93	− 0.38	− 0.39	− 0.12	+ 0.26	− 0.37	+ 10.5	1727.7	.	B	$\frac{1}{2}$
171	0 = − 0.89	− 0.41	− 0.37	+ 0.18	− 0.39	+ 0.01	+ 16.4	"	.	B	$\frac{1}{2}$
172	0 = − 0.57	− 0.29	− 0.23	+ 0.36	− 0.82	+ 0.35	+ 9.2	"	.	B	$\frac{1}{2}$
173	0 = − 0.93	− 0.40	− 0.37	+ 0.13	− 0.29	0.00	+ 12.2	"	.	B	$\frac{1}{2}$

CASSINI, ETC.—SERIES II—Continued.

Number.	Equation.	Year.	Phase.	Limb.	Wt.
174	$0 = +0.79\delta\varepsilon + 0.35\delta t + 0.31e\delta\varpi - 0.26i\delta\theta + 0.58\delta b_0 - 0.20\delta\Pi - 9.0''$	1727.7	E	.	0
175	$0 = +0.97 \quad +0.38 \quad +0.38 \quad +0.03 \quad -0.07 \quad +0.09 \quad -39.7$	"	E	.	0
176	$0 = +0.79 \quad +0.28 \quad +0.30 \quad +0.26 \quad -0.59 \quad +0.28 \quad -3.7$	"	E	.	0
177	$0 = +0.97 \quad +0.38 \quad +0.37 \quad -0.01 \quad +0.03 \quad -0.06 \quad -9.6$	"	E	.	0
178	$0 = -0.88 \quad -0.34 \quad -1.70 \quad +0.02 \quad -0.34 \quad +0.30 \quad +3.7$	1738.0	.	.	1
179	$0 = +0.90 \quad +0.35 \quad +1.76 \quad +0.02 \quad -0.25 \quad -0.22 \quad -4.7$	"	E	B	½
180	$0 = -0.85 \quad -0.40 \quad -1.78 \quad -0.13 \quad +0.36 \quad -0.72 \quad -0.3$	1739.0	.	.	1
181	$0 = +0.75 \quad +0.38 \quad +1.57 \quad -0.22 \quad +0.58 \quad -0.07 \quad -2.1$	"	E	B	½

DELISLE AT LUXEMBOURG.

Number.	Equation.	Year.	Phase.	Limb.	Wt.
183	$0 = -0.61\delta\varepsilon - 0.24\delta t - 0.20e\delta\varpi - 0.78i\delta\theta - 0.80\delta b_0 + 0.40\delta\Pi + 7.8$	1713.9	.	.	1
184	$0 = -0.66 \quad -0.37 \quad +0.14 \quad +0.76 \quad +0.76 \quad +0.02 \quad +6.1$	1714.2	.	.	1
185	$0 = -0.93 \quad -0.50 \quad -0.26 \quad +0.31 \quad +0.32 \quad +0.41 \quad +12.3$	"	.	.	1
186	$0 = -0.98 \quad -0.40 \quad +1.16 \quad +0.26 \quad -0.30 \quad +0.06 \quad +18.0$	1714.3	.	B	1
187	$0 = +0.98 \quad +0.38 \quad -1.17 \quad +0.28 \quad -0.32 \quad +0.34 \quad -14.9$	"	E	.	1
188	$0 = +0.98 \quad +0.54 \quad -0.93 \quad -0.39 \quad -0.39 \quad +0.84 \quad -12.9$	1714.7	E	.	1
189	$0 = +0.84 \quad +0.40 \quad +1.11 \quad -0.16 \quad -0.42 \quad +0.95 \quad -6.1$	1714.8	E	.	1
190	$0 = -1.04 \quad -0.61 \quad +1.34 \quad +0.04 \quad +0.08 \quad -0.60 \quad +13.5$	1717.7	.	B	1
191	$0 = +1.02 \quad +0.59 \quad -1.32 \quad +0.10 \quad +0.22 \quad +0.37 \quad -10.0$	"	E	.	1
192	$0 = -0.57 \quad -0.29 \quad +0.91 \quad -0.25 \quad +0.87 \quad -0.35 \quad +13.9$	1718.0	.	.	1
193	$0 = -1.03 \quad -0.40 \quad +0.94 \quad +0.07 \quad +0.19 \quad -0.10 \quad +15.3$	1718.1	.	.	1
194	$0 = -0.60 \quad -0.24 \quad -0.16 \quad +0.76 \quad +0.76 \quad -0.83 \quad +5.4$	1718.7	.	.	½
195	$0 = -0.84 \quad -0.41 \quad -0.60 \quad +0.02 \quad -0.49 \quad +0.95 \quad +9.9$	1719.3	.	.	1
196	$0 = +0.73 \quad +0.44 \quad +0.52 \quad +0.03 \quad -0.64 \quad -0.22 \quad -3.2$	"	E	B	0
197	$0 = -1.04 \quad -0.44 \quad +1.64 \quad +0.03 \quad -0.26 \quad +0.39 \quad +10.1$	1719.6	.	.	1
198	$0 = -0.75 \quad -0.42 \quad -1.12 \quad +0.12 \quad -0.60 \quad +0.06 \quad -1.3$	1719.8	.	B	1
199	$0 = +0.85 \quad +0.38 \quad +1.26 \quad +0.08 \quad -0.41 \quad +0.69 \quad +2.4$	"	E	.	0
200	$0 = -1.06 \quad -0.58 \quad +1.98 \quad +0.16 \quad -0.17 \quad +0.92 \quad +13.0$	1725.1	.	.	1

DELISLE AT ST. PETERSBURG.

Number.	Equation.	Year.	Phase.	Limb.	Wt.
201	$0 = -0.99\delta\varepsilon - 0.47\delta t + 0.31e\delta\varpi + 0.01i\delta\theta - 0.02\delta b_0 + 0.65\delta\Pi + 4.7$	1727.2	.	.	.
202	$0 = -0.88 \quad -0.48 \quad -1.84 \quad +0.07 \quad +0.23 \quad +0.50 \quad +3.6$	1729.9	.	.	.
203	$0 = -0.78 \quad -0.40 \quad -1.63 \quad -0.15 \quad -0.51 \quad +0.91 \quad +1.0$	"	.	.	.
204	$0 = -0.60 \quad -0.35 \quad -1.26 \quad -0.23 \quad -0.75 \quad +0.96 \quad +2.4$	"	.	.	.
205	$0 = -0.25 \quad -0.18 \quad -0.53 \quad +0.29 \quad +0.96 \quad -0.50 \quad -1.0$	"	.	.	.
206	$0 = -0.79 \quad -0.47 \quad -1.66 \quad +0.15 \quad +0.48 \quad +0.22 \quad +3.5$	"	.	.	.
207	$0 = -0.78 \quad -0.49 \quad -1.64 \quad +0.16 \quad +0.50 \quad +0.16 \quad +2.8$	"	.	.	.
208	$0 = -0.53 \quad -0.36 \quad -1.11 \quad +0.25 \quad +0.81 \quad -0.26 \quad +0.7$	"	.	.	.
209	$0 = -1.00 \quad -0.43 \quad +1.01 \quad -0.23 \quad -0.26 \quad +0.27 \quad +16.5$	1733.2	.	.	.
210	$0 = -0.49 \quad -0.23 \quad -0.13 \quad +0.34 \quad +0.88 \quad -0.76 \quad -14.6$	"	.	.	.
211	$0 = -0.79 \quad -0.50 \quad +0.27 \quad +0.30 \quad +0.61 \quad -0.05 \quad +7.2$	1736.3	.	.	.
212	$0 = -1.00 \quad -0.42 \quad -0.10 \quad +0.64 \quad +0.16 \quad -0.63 \quad +6.7$	1736.6	.	B	.
213	$0 = +0.98 \quad +0.42 \quad +0.08 \quad +0.11 \quad +0.27 \quad -0.25 \quad +4.7$	"	E	.	.
214	$0 = -0.97 \quad -0.41 \quad -0.43 \quad -0.01 \quad -0.21 \quad +0.19 \quad +5.3$	1736.8	.	B	.

DELISLE AT ST. PETERSBURG—Continued.

Number.	Equation.							Year.	Phase.	Limb.	Wt.
							″				
215	0 = + 0.97 $\delta\varepsilon$	+ 0.42 δt	+ 0.40 $e\delta\varpi$	0.00 $i\delta\theta$	0.00 δb_0	− 0.32 $\delta\Pi$	+ 4.3	1736.8	E	.	.
216	0 = − 1.02	− 0.49	+ 1.18	+ 0.19	− 0.22	+ 0.39	+ 8.6	1737.4	.	.	.
219	0 = + 0.41	+ 0.20	+ 0.64	− 0.11	− 0.90	+ 0.98	− 9.2	1737.6	E	.	.
220	0 = + 0.82	+ 0.45	+ 1.26	− 0.06	− 0.49	+ 0.76	− 3.2	"	E	.	.
221	0 = − 0.54	− 0.22	+ 1.17	− 0.01	+ 0.82	− 0.77	− 1.9	1738.0	.	.	.
222	0 = − 0.93	− 0.41	− 1.85	0.00	− 0.04	− 0.08	+ 5.2	"	.	.	.
223	0 = − 0.86	− 0.37	− 1.74	− 0.01	+ 0.35	− 0.35	+ 3.2	"	.	.	.
224	0 = − 0.82	− 0.36	− 1.18	+ 0.02	− 0.48	+ 0.38	+ 7.1	"	.	.	.
225	0 = − 0.54	− 0.23	− 1.05	+ 0.06	− 0.82	+ 0.81	+ 4.4	"	.	.	.
226	0 = + 0.50	+ 0.25	+ 0.97	+ 0.07	− 0.85	+ 0.28	− 1.2	"	E	B	.
227	0 = − 0.50	− 0.24	− 0.37	+ 0.07	− 0.87	+ 0.42	+ 4.4	1738.1	.	.	.
228	0 = − 0.78	− 0.36	− 1.73	− 0.11	+ 0.52	− 0.66	+ 1.9	1738.6	.	B	.
229	0 = + 0.69	+ 0.35	+ 1.52	− 0.15	+ 0.66	− 0.37	+ 0.5	"	E	.	.
230	0 = − 0.88	− 0.41	− 1.95	+ 0.06	− 0.26	+ 0.04	+ 10.9	"	.	B	.
231	0 = − 0.91	− 0.42	− 2.00	− 0.03	+ 0.12	− 0.11	− 5.4	"	.	B	.
232	0 = − 0.58	− 0.25	− 1.29	+ 0.21	− 0.78	+ 0.75	+ 1.1	"	.	B	.
233	0 = + 0.61	+ 0.29	+ 1.35	+ 0.21	− 0.75	+ 0.16	+ 38.8	"	E	.	.
234	0 = − 0.74	− 0.38	− 1.61	+ 0.18	− 0.59	+ 0.28	− 1.4	1738.8	.	B	.
235	0 = + 0.82	+ 0.35	+ 1.80	+ 0.14	− 0.43	+ 0.49	+ 2.7	"	E	.	.
236	0 = − 0.88	− 0.43	− 1.96	+ 0.22	− 0.22	− 0.32	+ 3.0	1739.8	.	B	.
237	0 = + 0.90	+ 0.40	+ 2.00	+ 0.10	− 0.10	+ 0.44	0.0	"	E	.	.
238	0 = − 0.90	− 0.46	− 1.99	+ 0.05	− 0.05	− 0.56	− 1.7	"	.	B	.
239	0 = + 0.90	+ 0.43	+ 1.98	− 0.07	+ 0.07	+ 0.50	+ 2.8	"	E	.	.
240	0 = − 0.91	− 0.46	− 1.48	+ 0.03	− 0.07	+ 0.73	+ 1.7	1746.2	.	.	.
241	0 = − 0.53	− 0.25	− 0.85	+ 0.37	− 0.82	+ 0.87	+ 0.6	"	.	.	.
242	0 = − 0.56	− 0.33	− 0.91	− 0.35	+ 0.79	− 0.05	− 1.8	"	.	.	.
243	0 = − 0.87	− 0.48	− 1.39	− 0.14	+ 0.31	+ 0.48	− 0.8	"	.	.	.
244	0 = − 0.85	− 0.47	− 1.36	− 0.16	+ 0.37	+ 0.42	+ 1.3	"	.	.	.
245	0 = − 0.80	− 0.47	− 1.26	− 0.21	+ 0.49	+ 0.28	− 1.3	"	.	.	.
246	0 = − 0.90	− 0.48	− 1.45	+ 0.08	− 0.18	+ 0.80	+ 0.7	"	.	.	.
247	0 = − 0.90	− 0.47	− 1.45	+ 0.07	− 0.15	+ 0.79	+ 0.2	"	.	.	.
248	0 = − 0.45	− 0.20	− 0.71	+ 0.39	− 0.88	+ 0.88	+ 0.8	"	.	.	.
249	0 = − 0.84	− 0.44	− 1.36	+ 0.17	− 0.39	+ 0.89	+ 1.1	"	.	.	.
250	0 = − 0.89	− 0.49	− 1.41	− 0.11	+ 0.25	+ 0.53	+ 0.6	"	.	.	.
251	0 = − 0.89	− 0.49	− 1.42	− 0.10	+ 0.22	+ 0.55	+ 2.2	"	.	.	.
252	0 = − 0.82	− 0.44	− 1.30	+ 0.19	− 0.44	+ 0.93	− 0.7	"	.	.	.
253	0 = − 0.46	− 0.27	− 1.01	− 0.16	+ 0.87	− 1.18	+ 0.2	1747.1	.	.	.
254	0 = − 0.88	− 0.46	− 1.94	− 0.05	+ 0.25	+ 0.51	0.0	"	.	.	.
255	0 = − 0.91	− 0.48	− 2.00	0.00	0.00	+ 0.69	+ 3.2	"	.	.	.
256	0 = − 0.64	− 0.37	− 1.41	− 0.13	− 0.71	+ 0.04	+ 2.9	"	.	.	.
257	0 = − 0.90	− 0.48	− 1.98	− 0.23	+ 0.12	+ 0.75	+ 0.8	"	.	.	.
258	0 = + 0.90	+ 0.49	+ 1.89	0.00	− 0.14	+ 0.42	0.0	1747.6	E	.	.
259	0 = + 0.79	+ 0.46	+ 1.67	− 0.01	+ 0.49	− 0.16	+ 0.3	"	E	.	.
260	0 = + 0.82	+ 0.47	+ 1.73	− 0.01	+ 0.42	− 0.09	− 0.2	"	E	.	.

FLAMSTEED.

Number.	Equation.							Year.	Phase.	Limb.	Wt.
							″				
261	$0 = -0.80\delta\varepsilon$	$-0.36\delta t$	$-1.78e\delta\varpi$	$-0.36i\delta\theta$	$-0.47\delta b_0$	$+0.84\delta\Pi$	+31.2	1676.2	.	.	1
262	$0 = -0.71$	−0.36	−0.57	−0.62	−0.67	+0.90	+28.3	"	.	.	1
263	$0 = +1.01$	+0.49	−0.05	+0.03	−0.09	+0.29	+9.5	1676.5	E	.	0
264	$0 = -0.93$	−0.38	+1.48	+0.48	−0.52	+0.55	+103.6	1676.6	.	.	0
265	$0 = -0.81$	−0.47	−1.77	−0.43	−0.43	−0.25	−40.4	1676.7	.	B	0
266	$0 = +0.89$	+0.44	+1.94	−0.19	−0.18	+0.72	+26.4	"	E	.	0
267	$0 = -0.98$	−0.39	+1.62	−0.42	+0.47	+0.03	+34.5	1676.8	.	.	1
269	$0 = -1.01$	−0.39	+1.41	−0.14	+0.34	−0.13	+28.0	1678.7	.	.	1
272	$0 = -0.95$	−0.43	−0.25	−0.15	+0.34	−0.80	+33.9	1680.0	.	B	1
273	$0 = +0.93$	+0.41	+0.27	−0.17	+0.38	+0.33	−4.9	"	E	.	0
274	$0 = -1.05$	−0.43	+1.90	+0.12	+0.28	−0.35	+24.9	1680.7	.	B	1
275	$0 = +0.99$	+0.41	−1.78	+0.18	+0.44	−0.24	−21.7	"	E	.	1
276	$0 = -1.17$	−0.61	+2.00	−0.01	−0.03	−0.49	+37.9	1680.9	.	B	1
277	$0 = +1.16$	+0.58	−1.99	+0.05	+0.14	+0.36	−36.4	"	E	.	1
278	$0 = -1.03$	−0.52	+1.38	+0.01	−0.19	+0.84	+34.0	1682.2	.	.	1
279	$0 = +0.98$	+0.56	+1.33	0.00	−0.34	−0.51	−29.8	"	E	B	0
280	$0 = -0.81$	−0.43	+0.26	−0.18	+0.61	+0.26	+23.4	1683.1	.	.	1
281	$0 = +0.87$	+0.43	−0.29	−0.13	+0.52	−0.97	−12.7	"	E	B	0
282	$0 = -0.93$	−0.46	+0.65	−0.23	+0.38	+0.39	+24.2	1683.3	.	.	1
283	$0 = +0.98$	+0.48	−0.69	−0.15	+0.25	−0.82	+8.6	"	E	B	0
284	$0 = -0.70$	−0.36	+1.28	−0.74	+0.77	−0.40	+16.9	"	.	.	1
285	$0 = +0.83$	+0.36	−1.52	−0.62	+0.64	−0.75	−29.2	"	E	B	0

PROVISIONAL SOLUTION OF THE PRECEDING EQUATIONS.

Observations of BULLIALDUS *and* GASSENDUS.

The only quantity which can be obtained from these observations is a rough mean correction to the moon's mean longitude. All the observations used were immersions at the dark limb, except in the case of the comparatively bright star μ Geminorum, of which the immersion was observed when the moon was full. The principal error to be feared is therefore in the determination of the time, which was derived by observing an altitude at the moment of the phenomenon. The probable error of each equation will be nearly proportional to $\frac{dD}{dt}$, and this, again, is nearly proportional to the coefficient of $\delta\varepsilon$. Hence, if we derive separate values of $\delta\varepsilon$ from each equation, the results will be entitled to nearly equal weight, supposing the times determined with equal precision. In combining the observations, however, I have, for an obvious reason, given only half weight when the object whose altitude was observed was less than two hours from the meridian, and also to the confused observation of γ Capricorni, on 1635, August 26. I have also given only weight $\frac{1}{3}$ to each of the three observations by BULLIALDUS which were not hopelessly erroneous. Observations at the bright limb are passed over without remark. The last observation is rejected entirely on account of discordance, and doubt respecting place of observation.

The separate results thus obtained are:—

1635.0	$\delta\varepsilon = -125''$	Wt. $= \frac{1}{3}$
39.3	$+114$	$\frac{1}{3}$
41.3	$+13$	$\frac{1}{3}$
1627.5	$\delta\varepsilon = +41''$	Wt. $= 1$
27.7	$+69$	$\frac{1}{2}$
32.1	$+29$	$\frac{1}{2}$
35.7	$+148$	$\frac{1}{2}$
37.2	$+102$	1
37.2	$+69$	1
37.2	$+68$	1
37.2	$+85$	1
38.1	$+48$	1
38.1	$+10$	1

The mean result is:—

$$\text{Epoch, } 1635.7: \quad \delta\varepsilon = +57'' \pm 9''; \quad \delta\varepsilon' = +3.8''.$$

The quantity $\delta\varepsilon'$ here represents the mean correction when HANSEN's empirical term is removed.

Observations of HEVELIUS.

The treatment of the immersions observed by HEVELIUS does not offer any serious difficulty; but the frequency of cases in which it is clear from the result that the emersion was observed too late renders the use of the emersions doubtful. We shall divide the observations into groups, so as to obtain corrections for various mean epochs.

Group, 1644–1645.—The two occultations of α Tauri give very satisfactorily:—

$$\text{Epoch, } 1645.2\text{: } \delta\varepsilon = +33''.6\text{; } \delta\varepsilon' = +12'' \pm 8''.$$

Group, 1658–64.—The emersion of β Scorpii, 1660, April 26, HEVELIUS considered well observed, and the result seems good. The other two emersions I reject. The result thus obtained is:—

$$\text{Epoch, } 1662.0\text{: } \delta\varepsilon = +38'' \pm 4''\text{; } \delta\varepsilon' = +18''.$$

Group, 1671–75.—The immersions are all used, although the occultations of the Pleiades on 1674, August 23, were observed at the bright limb. I judge from the observations and other considerations that HEVELIUS could follow the stars of the Pleiades close up to the limb of the moon. The emersions are all rejected. The results are:—

$$\text{Epoch, } 1673.9\text{: } \delta\varepsilon = +39''.2 \pm 3''.4\text{; } \delta\varepsilon' = +22''.$$

Group, 1676–83.—Here, although HEVELIUS's clock-error seemed better determined than before, the observations exhibit anomalies which cannot be attributed to the apparent accidental errors of observation, and which, therefore, leave one in doubt how the results should be treated. As the results cannot be worth a refined discussion, I shall simply state how I have used the equations. The emersions of Mars and of α Tauri have been retained, while, as before, all other emersions are rejected. The results from χ Orionis, 1678, March 28, (No. 62), and from the three stars occulted 1683, April 2, (Nos. 75–77), have been rejected on account of discordance of results. In the first case, the identity of the star is still in doubt, while in the second there was an interval of nearly two hours between the first occultation and the determination of clock-error, during which interval the error had to be supposed constant. The results of the occultations seem to indicate a large clock-rate. There remain nine equations, of which the sum has been taken as a normal for determining $\delta\varepsilon$. This equation is:—

$$8.44\ \delta\varepsilon = 264'' \pm 40''\text{;}$$

and the result is:—

$$\text{Epoch, } 1680.0\text{: } \delta\varepsilon = +31'' \pm 5''\text{; } \delta\varepsilon' = +16''.$$

The close agreement of the four mean results derived from the observations of HEVELIUS is purely accidental; the discordance of the individual equations in general indicates that the probable errors we have assigned may be safely increased by one third.

Observations of the French astronomers and of FLAMSTEED.

A preliminary examination of these observations indicated that there was no systematic difference between the results of the occultations observed by FLAMSTEED and those observed by the French astronomers. They have therefore been combined, and solved so as to obtain corrections to the moon's mean longitude and to the longitude of the node. In effecting these solutions, we meet with the difficulty that the correc-

tion to the tabular mean longitude cannot be regarded as increasing uniformly for any considerable length of time. On the other hand, when we divide the observations into groups, the duration of each group is too small to permit an accurate determination of the correction of mean motion from that group alone. The following course appeared best adapted for the present preliminary solution. Rough solutions were first made so as to give the value of $\delta\varepsilon$ alone for the mean epochs of the great groups into which the observations were divided. Thus was found:—

For 1680, $\delta\varepsilon = +30''.4$, FLAMSTEED'S observations.
For 1682, $\delta\varepsilon = +28''.5$, Paris observations.
For 1710, $\delta\varepsilon = +15''.4$, Paris observations.
For 1715, $\delta\varepsilon = +13''.8$, DELISLE'S observations.
For 1728.5, $\delta\varepsilon = +\ 7''.3$, Paris and DELISLE'S observations.

From these values of the correction of mean longitude, it was concluded that the corrections to the tabular mean motion might be assumed to have the following values:—

From 1672 to 1690, $\delta n = -0''.35$.
From 1699 to 1720, $\delta n = -0''.55$.

With these assumed annual changes, each residual of an equation was reduced to a mean epoch of its group, all the observations to 1720 being divided into two groups. The adopted mean epoch for the first period, 1672 to 1690, was 1680.0; that for the second, 1699–1720, was 1712.5. In other words, the absolute term of each equation was corrected by the quantity $0''.35\,k\,(1680.0 - t)$ for the first group, and by the quantity $0.''55\,k\,(1712.5 - t)$ for the second, k being the coefficient of $\delta\varepsilon$ in the equation.

In the solution, the unknown quantities retained were $\delta\varepsilon$, $i\delta\theta$, and δb_0, the last being an assumed constant correction to the moon's latitude. This was kept in the equations, because a constant error in the declinations, and therefore in the latitudes of the stars, is to be expected, and will show itself in the equations as a constant apparent correction to the moon's latitude.

The weights assigned to the several equations are shown in the last column. The probable error depends mainly upon the errors of theory and of the place of the star, so that no distinction with respect to weight was necessary in the case of fair observations. As a general rule, emersions were rejected unless there was positive reason to believe that the reappearance of the star had actually been caught at the right moment. The solutions with the assigned weights lead to the following results:—

First group, CASSINI, FLAMSTEED, LA HIRE, 1672–1690.

Normal Equations.

$$
\begin{array}{rrrrl}
18.423\,\delta\varepsilon & +\,2.613\,i\delta\theta & -\,1.521\,\delta b_0 & -\,538''.27 & =0 \\
2.613 & +\,4.750 & -\,3.940 & -\,66''.84 & =0 \\
-\,1.521 & -\,3.940 & +\,7.059 & +\,25''.59 & =0.
\end{array}
$$

Solution.

$$\delta\varepsilon = +29''.41, \text{ epoch } 1680.0.$$
$$i\delta\theta = +\ 0''.26.$$
$$\delta b_0 = +\ 2''.86, \text{ weight} = 3.8.$$

Second group, CASSINI, LA HIRE, DELISLE, 1699–1720.

Normal Equations.

$$\begin{array}{rrrrl} 31.65\ \delta\varepsilon & -2.321\ i\delta\theta & +\ 0.753\ \delta b_0 & -466''.84 & =0 \\ -2.321 & +5.970 & +\ 4.876 & +\ 25''.84 & =0 \\ 0.753 & +4.876 & +17.63 & -\ 29''.31 & =0. \end{array}$$

Solution.

$$\delta\varepsilon = +14''.78, \text{ epoch } 1712.5.$$
$$i\delta\theta = +\ 0''.75.$$
$$\delta b_0 = +\ 0''.82, \text{ weight} = 13.4.$$

The corrections $i\delta\theta$ have a very small weight in both equations. Occultations do not afford good data for determining the correction to the moon's node, because, to be favorable, an observation must be not too far from the node, and must not be nearly central. A glance at the equations will show that the coefficient of $i\delta\theta$ amounts to 0.5 in less than half the equations. Moreover, owing to an accidental lack of symmetry in the occultations in each group, the value of $i\delta\theta$ depends very largely on that of δb_0, the approximate expressions being:—

From the first group, $i\delta\theta = \ 1''.47 - 0.85\ \delta b_0$.
From the second group, $i\delta\theta = -\ 2''.19 + 0.85\ \delta b_0$.

The actual value of δb_0 and $i\delta\theta$ should be considered nearly the same for both groups, being probably about one-fifth larger for the first group than for the second, since we may suppose them to vanish about 1850. The most probable values of δb_0, on this hypothesis, are:—

For the first group, $\delta b_0 = +\ 1''.5$.
For the second, $\delta b_0 = +\ 1''.2$.

Whence we shall obtain—

From the first group, $i\delta\theta = +\ 0''.2$.
From the second group, $i\delta\theta = -\ 1''.2$.

To obtain a really definitive result, we must combine both groups, supposing the values of $\delta\varepsilon$ independent, and putting—

$$i\delta\theta_2 = 0.80\ i\delta\theta_1,$$
$$\delta b_2 = 0.80\ \delta b_1,$$

the subscript numerals distinguishing the values which pertain to the two groups. The coefficient 0.80 presupposes that the position of the node and the tabular latitudes

of the stars are correct at the epoch 1842, which is about as good a hypothesis as we can make. The combination of the two groups has been made on the supposition that all the equations of the second group are first multiplied by 1.25, and that $i\delta\theta_2$ and δb_2 are then replaced by 0.80 $i\delta\vartheta_1$ and 0.80 δb_1. This course is taken because the residuals show that the unit of weight corresponds to a smaller probable error in the second group than in the first. The combined normals are:—

$$
\begin{array}{rrrrrl}
39.56\,\delta\varepsilon_2 & +\ 0.00\,\delta\varepsilon_1 & -\ 2.32\,i\delta\theta_1 & +\ 0.75\,\delta b_1 & -\ 583''.55 & = 0 \\
0.00 & +\ 18.43 & +\ 2.61 & -\ 1.52 & -\ 538''.27 & = 0 \\
-2.32 & +\ 2.61 & +\ 9.53 & -\ 0.04 & -\ 41''.00 & = 0 \\
0.75 & -\ 1.52 & -\ 0.04 & +\ 21.16 & -\ 3''.72 & = 0.
\end{array}
$$

The solution of these equations gives—

$$
\begin{array}{ll}
\delta\varepsilon_1 = +\ 29''.38 \pm 1''.0; & \text{epoch, } 1680.0. \\
\delta\varepsilon_2 = +\ 14''.78 \pm 0''.6; & \text{epoch, } 1712.5. \\
i\delta\theta_1 = -\ \ 0''.14 \pm 1''.2; & \text{weight} = 9. \\
\delta b_1 = +\ \ 1''.76 \pm 0''.8; & \text{weight} = 21.
\end{array}
$$

The probable error of each equation of weight unity is about 3''.6; and as all the equations of the second series were multiplied by the factor 1.25, the probable error of each observed distance of centre of moon from star would be about 3''.0, which is the error already estimated from errors of star-places and of the tabular perturbations and from the irregularities of the moon's limb. It is, therefore, from these sources, rather than from errors of the observed times, that the errors of the equations arise, so that, when, in the course of time, the tabular perturbations and the places of the stars are more accurately determined, more accurate results may be obtained from these occultations.

Observations of CASSINI *at Paris and* DELISLE *at St. Petersburg, between* 1720 *and* 1750.

I have not attempted any serious discussion of these observations, having merely sought to obtain from them an approximate correction to the mean longitude for some epoch near 1725. From the good observations between 1725 and 1730 inclusive, we find:—

$$\text{Epoch, } 1728.5\text{: } \delta\varepsilon = +\ 7''.3 \text{ (8 observations)},$$

a result I look upon with a suspicion of its being a little too large, owing to several of the observations on which it depends having been made at the moon's bright limb.

§ 14.

OBSERVATIONS OF ECLIPSES FROM 1620 TO 1724.

The tabular places of the sun which are used in the reduction of these eclipses were accidentally omitted in § 11, where the corresponding places of the moon are given. They are, therefore, given in the following table. They were generally computed for different mean times by different computers, in order that the comparison of the results might serve as a check on the accuracy of the work. The original results are all presented.

Longitudes of the Sun, from HANSEN'S *Tables.*

Date.	Greenwich Mean Time.			Longitude Mean Equinox.		
	h	*m*	*s*	°	′	″
1621, May 20	12	0	0	59	54	17.2
" "	18	39	34	60	10	17.5
" "	21	5	10	60	16	6.7
" "	24	0	0	60	23	7.0
1633, Apr. 8	−	9	21	18	49	44.4
" "	4	48	0	19	1	53.7
1639, June 1	0	0	0	70	34	56.8
" "	3	36	0	70	43	33.2
" "	12	0	0	71	3	38.7
1645, Aug. 21	0	0	0	148	34	19.5
1652, Apr. 8	0	0	0	19	13	46.4
1654, Aug. 11	12	0	0	139	14	52.0
" "	20	0	0	139	34	4.9
" "	24	0	0	139	43	42.3
1656, Jan. 26	0	0	0	306	20	48.4
" "	0	30	0	306	22	4.6
" "	12	0	0	306	51	15.8
1675, June 22	16	0	0	91	33	18.9
1661, Mar. 29	12	0	0	9	43	36.3
" "	21	0	0	10	5	48.0
1666, July 1	12	0	0	100	8	14.7
" "	17	36	0	100	21	35.2
" "	24	0	0	100	36	50.3
1676, June 10	12	0	0	80	40	27.8
" "	20	0	0	80	59	33.3
" "	24	0	0	81	9	6.0
1684, July 12	0	0	0	110	46	12.2
" "	2	16	0	110	51	36.8
" "	12	0	0	111	14	49.5
1687, May 11	0	0	0	50	48	33.9
" "	1	0	0	50	50	58.0
" "	12	0	0	51	17	27.5
1689, Sept. 13	0	0	0	171	14	54.4
" "	3	20	0	171	23	3.5
" "	12	0	0	171	44	12.9
1699, Sept. 22	12	0	0	180	8	18.3
" "	21	0	0	180	37	45.2
1706, May 11	12	0	0	50	42	54.2
" "	20	20	0	51	2	59.1
" "	24	0	0	51	11	48.5
1708, Sept. 13	12	0	0	171	9	8.0
" "	18	30	0	171	25	5.2
" "	24	0	0	171	38	30.5
1715, May 2	12	0	0	41	51	20.2
" "	19	12	0	42	8	45.5
" "	24	0	0	42	20	22.2
1724, May 22	0	0	0	61	26	25.8
" "	12	0	0	61	55	13.2
" "	24	0	0	62	24	0.0

The observations in question may be divided into two classes: observations of contacts and of phases. The latter were generally estimated by throwing the sun's image upon a screen so adjusted that the outline of the image should coincide with a circle drawn on the screen. The radius of this circle was divided into 12, 30, or 32 parts by concentric circles, so that the corresponding phases of the eclipse could be observed. The absolute magnitude of a phase thus determined is necessarily too

uncertain to be relied on, owing to the effect of irradiation and distortion of image; but, so far as longitude is concerned, this effect will act in opposite directions before and after the time of greatest eclipse. Therefore, by subtracting from each other the corresponding observations before and after the middle, we shall obtain results nearly free from the errors in question. This is the course which has been generally adopted in the discussion of these observations. Whenever possible, observations at nearly equal distances on each side of the middle have alone been compared, the mean of two or more being sometimes combined with a single corresponding one on the opposite side. When the observations were so broken that there was no correspondence, the combination was made in the way which seemed adapted to give the most probable result.

The details of reduction are presented pretty fully in the following forms:—Under the head of each eclipse is given the apparent semi-diameter of the the moon as seen from the station at the beginning and at the end of the eclipse, computed with the same data and in the same way as in the case of occultations. The sun's apparent semi-diameter is computed by supposing its value at distance unity to be 960″. In some cases, however, it may not exactly correspond to this constant, some value a little different being used. Any small error in the semi-diameter being in great part eliminated from the result, no great pains were taken with it.

The local mean times of the observed phases are, for the most part, derived from data already given by applying the clock-corrections derived from altitudes or other sources. In the observations of GASSENDUS, the times are derived immediately from the observed altitudes.

This time being reduced to Greenwich mean time, the apparent position of the moon as seen from the station is computed in the same way as for the occultations, except that, instead of using the parallax of the moon, only the difference of parallaxes of the sun and moon are employed. From this reduced position of the moon, and from the geocentric position of the sun, are derived the tabular distance of the centres, which is given in the column following the mean times. To this tabular distance is added its differential coefficient with respect to the moon's mean longitude.

This is followed by the observed distance of centres as derived from the contacts or measures of phase made by the observers, the formulæ being:—

$$D = s + s' - m,$$

m being the magnitude of the eclipse, which was usually expressed in terms of the sun's semi-diameter, and s and s' the apparent semi-diameters of the sun and moon respectively. If Δ expressed the number of digits eclipsed, we should have:—

$$m = \frac{\Delta s}{6}.$$

In the case of contacts, m would represent the magnitude of the least noticeable eclipse at beginning, or the magnitude immediately less than the least visible at ending. These two values of m are represented by α_1 and α_2, and in combining observations of contacts we have always supposed—

$$\alpha_1 = 2\ \alpha_2.$$

At the same time, double weight is always given to an observation of ending, as compared with that of beginning, because the observer is less likely to fail in noting the

time when the eclipse disappears than when it appears. By this combination, the mean result from the beginning and end of an eclipse is independent of the value which may be assigned to α_2, and therefore does not require any investigation of the value of that quantity. We may simply regard α_1 and α_2 as zero, and give double weight to the observation of the end of the eclipse as compared with that of beginning.

In combining observations of contacts and phases to obtain a mean result, it has generally been supposed that one pair of contacts is worth three or four pairs of observations of phase, the proportion varying with the apparent accuracy of the observations of phase. In a few cases, weights are assigned to the observations of phases; but, in general, there are no data for such an assignment.

To facilitate the final discussion, the difference between each observed and tabular distance is given for each separate observation. This difference is the absolute term of an equation containing $\delta\varepsilon$, and an unknown combination of quantities depending on errors in the mode of observation, which are supposed to be a function of D. This combination is eliminated from each pair of observations, at equal distances on each side of the middle, in the manner already described, leaving an equation in ε alone. It has not been considered necessary to write down the individual equations thus formed. The most probable results, generally obtained by combining the equations in a summary manner, approximately, though not strictly by the method of least squares, are given in connection with each set of observations.

Eclipse of 1621, *May* 20, *observed by* GASSENDUS *at Aix.*

Moon's apparent semi-diameter at beginning	. . . . . .	$936''.4$
Moon's apparent semi-diameter at end	. . . .	$942''.7$
Sun's apparent semi-diameter	. . . .	$949''.0$
Local M. T., $19^h\ 1^m\ 37^s$.	Tabular distance of centres .	$1980''.7 - 1.00\ \delta\varepsilon$
	Observed distance of centres .	$1885''.4 - \alpha_1$
$21^h\ 27^m\ 17^s$.	Tabular distance of centres .	$1827''.4 + 0.93\ \delta\varepsilon$
	Observed distance of centres .	$1891''.7 - \alpha_2$.
Result from first contact	. . . .	$\delta\varepsilon = + 95'' + \alpha_1$
Result from last contact	. . . .	$\delta\varepsilon = + 69'' - \alpha_2$
Mean by weights	. . . .	$\delta\varepsilon = + 78''$.

The values of α come out negative, a result which can be attributed only to errors in the determinations of time.

Eclipse of 1630, *June* 10, *observed by* GASSENDUS *at Paris.*

Moon's apparent semi-diameter at beginning	. . . . . .	$946''.2$
Sun's apparent semi-diameter at beginning	. . . . . .	$946''.0$
At $6^h\ 15^m\ 1^s$.	Tabular distance of centres	$1912''.8$
	Observed distance of centres	$1892''.2 - \alpha_1$
Result of the observation of first contact	. . .	$\delta\varepsilon = + 20'' + \alpha_1$

The value of α_1 may be conjecturally estimated at $15''$, giving as the result

$$\delta\varepsilon = + 35''.$$

Eclipse of 1633, *April* 8, *observed by* GASSENDUS *at Digne.* (See p. 81.)

Moon's apparent semi-diameter at beginning . . 937″.5
Moon's apparent semi-diameter at end . . . . 932″.9
Sun's semi-diameter . . . . 957″.2

Obs. Alt. of ⊙.		Local Mean Time.		Tabular Dist. of Centres.		Observed Distance.	Corr. to Tabular Dist.	Wt.
°	′	h	m	′		′	′	
27	15:	3	57.6:	22.3	$-0.89\,\delta\varepsilon$	19.6:	− 2.7:	0
25	15:	4	9.2:	17.9	−0.82	16.4:	− 1.5::	0
22	3	4	27.5	11.8	−0.58	12.9	+ 1.1	1
21	33	4	30.3	11.1	−0.51	11.6	+ 0.5	1
20	48	4	34.6	10.2	−0.36	10.0	− 0.2	1
20	24	4	36.9	9.8	−0.26	9.7	− 0.1	1
19	30	4	42.0	9.4	−0.04	9.5	+ 0.1	0
19	2	4	44.6	9.4	+0.08	9.5	+ 0.1	0
18	16	4	49.9	9.8	+0.33	10.0	+ 0.2	0
16	51	4	56.9	11.2	+0.40	11.1	− 0.1	0
16	17	5	0.1	12.0	+0.65	11.6	− 0.4	0
15	54	5	2.2	12.7	+0.68	12.4	− 0.3	1
15	39	5	3.6	13.2	+0.71	13.4	+ 0.2	1
15	23	5	5.1	13.7	+0.74	14.0	+ 0.3	1
14	57	5	7.5	14.5	+0.77	15.0	+ 0.5	1
14	22	5	10.8	15.7	+0.82	16.9	+ 1.2	1
13	46	5	14.1	17.0	+0.84	17.4	+ 0.4	1
13	13	5	17.2	18.2	+0.86	18.2	0.0	1
12	44	5	20.0	19.4	+0.88	19.6	+ 0.2	1
12	34	5	20.9	19.7	+0.88	20.1	+ 0.4	1
12	11	5	23.0	20.6	+0.89	21.7	+ 1.1	1
11	38	5	26.1	22.0	+0.90	23.5	+ 1.5	1
11	19	5	27.9	22.7	+0.91	24.3	+ 1.6	1
10	45	5	31.0	24.1	+0.92	26.2 25.8	+ 1.9	2
9	52	5	36.0	26.3	+0.93	27.2 27.3	+ 1.0	3
9	5	5	40.4	28.4	+0.95	29.1 29.6	+ 1.1	4
8	5	5	46.1	31.07	+0.97	$31.50 - a_2$	+ 0.4	4

Where two observed distances are given, the second is from the degrees of the circumference eclipsed. A typographical error in the printed record of the first observation renders the time doubtful. The correspondence of the second observation to the time given is entirely conjectural. The nine or ten following ones are of very little weight for determining the moon's longitude; but the minuteness of the correction which they indicate to the tabular distance of centres, at the time of greatest eclipse, seems to show that GASSENDUS's determinations of the magnitude of the eclipse were nearly free from constant error. I have therefore used all the subsequent measures with the weights as given, and the resulting correction to the moon's mean longitude is

$$\delta\varepsilon = +0'.88 = +53''.$$

Eclipse of 1639, *June* 1, *observed by* GASCOIGNE *at Middletown.*

$\phi = 53° 45'$; $\lambda = 6^m 8^s$ W.

(See FLAMSTEED, *Historia Coelestis*, vol. i, p. 2.)

Moon's apparent semi-diameter at beginning . . . 939″.0
Moon's apparent semi-diameter at end . . . . . . 935″.4
Sun's apparent semi-diameter . . . . 945″.6

No. of Phase.	Obs. Alt. of ⊙.	Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.
	° ′	h m s	″	″	″
1	36 35	3 48 04	1936 − .95 $\delta\varepsilon$	1885 − a_1	− 51
2	33 51	4 6 58	1449 − .93	1450	+ 1
3	30 47	27 47	912 − .87	881	− 31
4	26 30	56 49	343 + .02	360	+ 17
5	25 58	5 0 27	348 + .31	369	+ 21
6	25 20	4 45	390 + .59	483	+ 93
7	23 23	18 0	668 + .91	748	+ 80
8	21 38	29 58	987 + .97	1059	+ 72
9	20 53	35 7	1132 + .98	1220	+ 88
10	20 11	39 56	1270 + .98	1315	+ 45
11	19 28	44 54	1415 + .99	1446	+ 31
12	18 12	53 42	1676 + .99	1700	+ 24
13	17 20	59 47	1858 + .99	1881 − a_2	+ 23

The contacts alone here give,

$$\delta\varepsilon = +33'', \text{ wt.} = 8.$$

Phase 2, compared with the mean of 10, 11, and 12, gives the equation $1.92\ \delta\varepsilon = +32''$, whence

$$\delta\varepsilon = +17'', \text{ wt.} = 4.$$

Phase 3, compared with the mean of 7 and 8, gives $1.81\ \delta\varepsilon = 106''$, whence

$$\delta\varepsilon = +59'', \text{ wt.} = 3.$$

Giving these results the respective weights assigned, we have, as the mean result,

$$\delta\varepsilon = +34'' \pm 10''.$$

Eclipse of 1639, *June* 1, *observed by* HORROX, *at or near Toxteth Park.*

$\phi = 53° 20'$; $\lambda = 11^m 48^s.4$ W. from Greenwich.

Moon's apparent semi-diameter at beginning . . 939″.1
Moon's apparent semi-diameter at end . . . . 935″.7
Sun's apparent semi-diameter . . . . 945″.6

Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.	Wt.
h m s	″	″	″	
3 43 18	$1911 - .94\,\delta\varepsilon$	$1886 - \alpha_1$	− 25	.
47 3	1817 − .94	1809*	− 8	2
50 48	1722 − .94	1697	− 25	.
53 33	1652 − .93	1629	− 23	2
59 3	1511 − .93	1507	− 4	.
4 3 48	1390 − .92	1381	− 9	.
8 48	1262 − .91	1255	− 7	.
10 3	1231 − .90	1223	− 8	.
12 18	1174 − .89	1160	− 14	.
17 33	1041 − .87	1002	− 39	.
20 18	972 − .86	941	− 31	2
26 3	827 − .81	813	− 14	.
32 3	689 − .75	655	− 34	.
35 48	603 − .70	591	− 12	2
43 33	455 − .46	454	− 1	2
48 3	397 − .21	401	+ 4	2
50 18	381 − .05	385	+ 4	.
57 18	397 + .44	417	+ 20	.
5 6 18	539 + .79	559	+ 20	2
9 33	610 + .84	622	+ 12	.
14 3	714 + .89	732	+ 18	2
21 33	910 + .95	937	+ 27	2
24 3	976 + .96	1000	+ 24	.
35 18	1292 + .98	1336	+ 44	.
38 33	1385 + .98	1441	+ 56	.
41 33	1472 + .99	1504	+ 32	.
43 48	1537 + .99	1578	+ 41	2
46 3	1603 + .99	1630	+ 27	.
48 18	1670 + .99	1693	+ 23	.
49 3	1692 + .99	1725	+ 33	.
54 33	$1846 + .99\,\delta\varepsilon$	$1883 - \alpha_2$	+ 37	.

* Derived from "Circumferentia Eclipsata" 33°.

The original observations are found in HORROX's *Opuscula Astronomica*, London, 1673, page 327, and again on page 388. I could not learn the exact position of HORROX: the longitude given above and employed is taken from a map, but the latitude is that given by HORROX.

The separate results for reducing the clock to mean time as derived from altitudes are:—

Clock Time.	Correction.
h m s	m s
2 30 0	− 2 26
2 38 0	− 2 37
3 18 45	− 2 37
4 15 15	− 0 50
5 17 45	− 1 58
5 59 30	− 1 3
6 5 45	− 2 6
6 7 15	− 3 1
6 8 45	− 2 46
6 10 30	− 2 46
6 12 45	− 2 20
6 17 15	− 1 55
Mean	− 2 12 ± 8ˢ

The contacts alone give . . . . $\delta\varepsilon = +34''$;
The observations of phase . . . . . . $\delta\varepsilon = +27''$ (12 pairs);
The phase from angle eclipsed . . . . . $\delta\varepsilon = +\ 8''$.

The most probable mean from all the observations,

$$\delta\varepsilon = +27''.$$

Judging from the discordance of the measures, the probable error of this result would not exceed 3″; but the possibility of systematic error must be taken into account. We can hardly suppose a set of observations made at this epoch to have a probable error less than 5″; and when we add the uncertainties respecting clock-error and geographical position, the probable error may be increased to 8″ or 9″.

Eclipse of 1639, *June* 1.2, *observed by* GASSENDUS *at Aix.*

$\phi = 43^\circ\ 32'$; $\lambda = 21^m\ 47^s$ W.

Moon's apparent semi-diameter at beginning .	935″.0
Moon's apparent semi-diameter at end	930″.9
Sun's semi-diameter	947″.3

Obs. Alt. of ☉.	Local Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tabular Dist.	Obs. Alt. of ☉.	Local Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tabular Dist.
° ′	h m	′	′	′	° ′	h m	′	′	′
?	4 40.9	31.8 −0.89$\delta\varepsilon$	31.4−a_1	−0.4−a_1	19 45	5 30.3	12.1 −0.44$\delta\varepsilon$	11.8	−0.3
28 10:	43.3:	30.8 − .88	31.4−a_1	. .	19 30	31.7	11.7 − .40	11.1	−0.6
28 0	44.0	30.5 − .88	29.8	−0.7	19 25	32.2	11.6 − .37	10.8	−0.8
27 40	45.9	29.6 − .88	29.4	−0.2	19 5	34.1	11.1 − .30	10.3	−0.8
27 20	47.8	28.8 − .87	28.3	−0.5	18 55	35.0	10.9 − .26	10.2	−0.7
27 0	49.7	28.0 − .87	27.7	−0.3	18 36	36.8	10.7 . .	9.9	−0.8
26 37	51.9	27.1 − .86	27.1	0.0	18 0	40.2	10.1 . .	10.0	−0.1
26 10	54.3	26.0 − .85	25.7	−0.3	17 16	44.4	10.0 . .	9.9	−0.1
26 2	55.1	25.7 − .85	25.0	−0.7	16 40	47.8	10.2 . .	9.8	−0.4
25 30	58.0	24.4 − .84	24.5	+0.1	16 0	51.6	10.7 + .51	10.5	−0.2
25 24	58.6	24.2 − .84	23.7	−0.5	15 30	54.5	11.3 + .62	11.7	+0.4
25 0	5 0.8	23.2 − .83	22.8	−0.4	15 0	57.4	12.1 + .68	12.7	+0.6
24 40	2.7	22.4 − .83	21.9	−0.5	14 40	59.4	12.7 + .73	13.0	+0.3
24 25	4.1	21.8 − .82	20.9	−0.9	13 58	6 3.5	13.9 + .78	14.0	+0.1
24 5	6.0	21.1 − .80	20.0	−1.1	13 35	5.7	14.9 + .81	14.9	0.0
23 40	8.3	20.1 − .78	19.4	−0.7	13 25	6.7	15.3 + .82	15.5	+0.2
23 30	9.2	19.7 − .77	19.0	−0.7	13 5	8.6	16.1 + .84	16.2	+0.1
23 20	10.1	19.4 − .76	18.9	−0.5	12 48	10.2	16.7 + .85	16.8	+0.1
23 0	12.0	18.6 − .73	18.2	−0.4	11 18	19.1	20.6 + .91	21.1	+0.5
22 55	12.5	18.4 − .73	17.9	−0.5	11 0	20.9	21.5 + .91	21.5	0.0
22 30	14.8	17.5 − .72	16.7	−0.8	10 37	23.1	22.5 + .93	22.5	0.0
22 15	16.2	16.9 − .70	16.5	−0.4	10 27	24.1	23.0 + .93	22.8	−0.2
22 0	17.6	16.4 − .68	15.6	−0.8	10 10	25.8	23.8 + .94	23.4	−0.4
21 2	23.0	14.4 − .60	14.0	−0.4	10 0	26.8	24.3 + .94	24.1	−0.2
20 30	26.1	13.4 − .55	12.4	−1.0	9 45	28.3	25.0 + .95	25.0	0.0
20 20	27.0	13.1 − .53	11.9	−1.2	9 30	29.7	25.7 + .95	26.2	+0.5
20 3	28.6	12.6 − .49	11.8	−0.8	9 0	32.8	27.3 + .95	27.6	+0.3

The constant error in the observations of phase would seem to be very small. I have, therefore, used the first four certain observations of phase by themselves, and in the case of the remainder have combined observations after the middle with corresponding ones before. The result is

$$\delta\varepsilon = +0'.38 = +23''.$$

Eclipse of 1639, June 1, observed by HEVELIUS.

Moon's semi-diameter at beginning . 936″.5
Moon's semi-diameter at end . . . 932″.4
Sun's semi-diameter . . . . . . 947″.0

Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Obs. Dist. corr. for Irrad.	Corr. to Tabular Dist.	Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Obs. Dist. corr. for Irrad.	Corr. to Tabular Dist.
h m	′ ′	′	′	′	h m	′ ′	′	′	′
5 17.8	31.15 − 1.00 $\delta\varepsilon$	31.39 − a_1	31.4 − a_1	+0.3 − a_1	6 23.9	2.9 +0.99 $\delta\varepsilon$	6.7	4.3	+ 1.4
5 28.1	26.0 −1.00	26.3	25.8	−0.2	6 25.5	3.6 +0.99	7.1	4.7	+ 1.1
5 33.2	23.5 −1.00	24.8	24.1	+0.6	6 26.9	4.3 +0.99	7.4	5.1	+ 0.8
5 38.6	20.8 −1.00	24.1	23.4	+2.6	6 28.6	5.1 +0.99	7.7	5.4	+ 0.3
5 42.2	18.9 −1.00	21.9	21.0	+2.1	6 30.1	5.8 +1.00	8.5	6.3	+ 0.5
5 45.7	17.2 −0.99	20.0	18.9	+1.7	6 32.6	7.2 +1.00	10.7	8.7	+ 1.5
5 48.2	15.9 −0.99	19.1	17.9	+2.0	6 34.2	8.0 +1.00	11.2	9.3	+ 1.3
5 50.7	14.6 −0.99	18.5	17.3	+2.7	6 36.1	9.0 +1.00	12.1	10.3	+ 1.3
5 53.2	13.4 −0.99	17.7	16.4	+3.0	6 38.2	10.2 +1.00	13.0	11.3	+ 1.1
5 55.2	12.4 −0.98	15.6	14.1	+1.7	6 40.1	11.1 +1.00	14.0	12.4	+ 1.3
5 57.6	11.2 −0.98	14.0	12.3	+1.1	6 41.9	12.0 +1 00	15.6	14.1	+ 2.1
5 59.6	10.2 −0.98	13.4	11.6	+1.4	6 44.2	13.4 +1.00	17.2	15.9	+ 2.5
6 1.7	9.1 −0.98	13.1	11.3	+2.2	6 45.9	14.3 +1.00	18.1	16.9	+ 2.6
6 4.1	7.9 −0.97	12.5	10.6	+2.7	6 49.3	16.1 +1.00	19.0	17.8	+ 1.7
6 6.0	6.9 −0.97	12.0	10.1	+3.2	6 50.7	16.9 +1.00	19.7	18.6	+ 1.7
6 8.0	5.9 −0.96	11.2	9.2	+3.3	6 52.7	18.0 +1.00	20.8	19.8	+ 1.8
6 10.7	4.5 −0.95	9.3	7.1	+2.6	6 54.1	18.7 +1.00	21.4	20.5	+ 1.8
6 11.9	3.9 −0.92	8.0	5.7	+1.8	6 55.9	19.7 +1.00	22.2	21.4	+ 1.7
6 13.4	3.1 . .	7.4	5.0	+1.9	6 57.8	20.8 +1.00	22.5	21.7	+ 0.9
6 17.1	1.4 . .	4.9	2.3	+0.9	7 0.9	22.5 +1.00	22.8	22.0	− 0.5
6 18.1	1.2 . .	3.6	0.9	−0.3	7 3.5	23.9 +1.00	24.4	23.8	− 0.1
6 19.3	1.1 . .	4.0	1.3	+0.2	7 5.3	24.9 +1.00	25.0	24.4	− 0.5
6 21.0	1.5 +0.97	5.6	3.1	+1.6	7 6.7	25.7 +1.00	26.0	25.5	− 0.2
6 22.8	2.3 +0.99	6.2	3.6	+1.3	7 12.0	28.6 +1.00	31.3	31.3	(+ 2.7)

HEVELIUS gives a number of drawings of phases of this eclipse, showing that his instrument was altogether out of focus, the cusps of the sun being so rounded near the time of greatest phase that the arc of sunlight was of nearly equal breadth throughout. For this reason, and also because the times depend entirely on some kind of a sun-dial which may not have been in the meridian, this eclipse was in the first place rejected entirely. (See p. 88 for original note upon it.) But I afterward concluded to reduce it, if only to see what kind of a result would be obtained from the worst set of observations found in his work.

The irradiation seems, from the excess of about 3′ near the observations of greatest phase, to have been about one-tenth the sun's semi-diameter. In the column of corrected distances from observations, the observed eclipse is increased by its tenth part to allow for this. Owing to the uncertainty of the law of error, I have only combined observations of nearly equal phase on each side of the middle in the same way as with the eclipses of GASSENDUS. The contacts are rejected entirely, as there is clearly a mistake of several minutes in the observation of the end. The mean of

the first seventeen observations of phase gives an excess of observed distance before the middle of the eclipse of $2'.03$. The mean of the last twenty gives an excess of $1'.14$. This would indicate a tabular correction of

$$-27'',$$

a result to which scarcely any weight can be given, owing to the uncertainty whether the adjustment of the instrument really remained the same during the eclipse, and whether the dial was really free from error.

Eclipse of 1645, *August* 21, *observed by* HEVELIUS.

Moon's semi-diameter at beginning .	$959''.4$
Moon's semi-diameter at end . . .	$957''.4$
Sun's semi-diameter	$951''.2$

Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.	Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.
h m s	$''$	$''$	$''$	*h m s*	$''$	$''$	$''$
23 26 37	$1942 - 0.93\delta\varepsilon$	$1911 - a_1$	$-31 - a_1$	0 34 22	$720 - 0.22\delta\varepsilon$	762 (?)	(+ 42)
29 52	$1871 - 0.92$	1831	− 40	44 12	$682 + 0.10$	683	+ 1
36 22	$1732 - 0.90$	1672	− 60	48 22	$691 + 0.25$	722	+ 31
40 52	$1634 - 0.89$	1593	− 41	53 32	$717 + 0.42$	762	+ 45
45 22	$1541 - 0.87$	1514	− 27	57 37	$754 + 0.54$	801	+ 47
48 22	$1478 - 0.86$	1415	− 63	1 4 42	$844 + 0.67$	880	+ 36
58 52	$1265 - 0.82$	1237	− 28	8 52	$903 + 0.74$	960	+ 57
0 4 22	$1160 - 0.76$	1118	− 42	11 22	$943 + 0.78$	999	+ 56
10 22	$1048 - 0.72$	1039	− 9	15 12	$1013 + 0.82$	1078	+ 65
14 22	$981 - 0.66$	960	− 21	18 22	$1066 + 0.86$	1117	+ 51
19 22	$899 - 0.59$	880	− 19	22 2	$1152 + 0.89$	1191	+ 39
23 52	$835 - 0.50$	822	− 13	26 37	$1226 + 0.91$	1276	+ 50
24 52	$822 - 0.48$	801	− 21	34 22	$1386 + 0.95$	1434	+ 48
27 52	$784 - 0.41$	781	− 3	50 22	$1730 + 0.98$	1790	+ 60
29 52	$761 - 0.36$	762	+ 1	51 52	$1770 + 0.98$	1830	+ 60
32 52	$733 - 0.27$	742	+ 9	55 52	$1861 + 0.99$	$1909 - a_2$	$+48 - a_2$

A system of twelve equations of condition is formed by subtracting the first twelve residuals from the last twelve, contact results excepted. The solution of these equations, slightly greater weight being given to those near the beginning and end of the eclipse, gives

$$\delta\varepsilon = +54''.$$

From the contacts we have:—

Beginning . . . . $\delta\varepsilon = +31'' + \alpha_1;$
End . . . . $+48'' - \alpha_2;$

from which, supposing $\alpha_1 = 2\,\alpha_2$, we have $\delta\varepsilon = +42''$. I take, as the most probable result from this eclipse,

$$\delta\varepsilon = +51''.$$

Eclipse of 1652, April 7, observed by GASSENDUS *at Digne.*

The end of this eclipse occurred within a few minutes of noon, and it is not likely that any reliance can be placed upon the times deduced from altitudes during the last hour of the eclipse. I have, therefore, concluded to make no use of the observations of GASSENDUS.

Eclipse of 1652, April 7–8, observed by HEVELIUS.

Moon's apparent semi-diameter at beginning .	997″.7
Moon's apparent semi-diameter at end . . .	996″.8
Sun's semi-diameter	957″.8

Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.		Corr. to Tab. Distance.		Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.		Corr. to Tab. Distance.	
h m s	′	″	″	″	″	h m s	″	″	″	″	″
23 5 27	$1919-1.10\delta\varepsilon$	$1955-\alpha_1$		+36	+36	0 9 9	$538-0.42\delta\varepsilon$	509		−29	
16 32	1629−1.10	1604	1579	−25	−50	12 34	528−0.24	459		−69	
18 30	1558−1.10	1536	1509	−22	−49	14 15	527−0.14	499		−28	
21 2	1515−1.09	1516	1487	+ 1	−28	27 55	652+0.51	638		−14	
22 52	1470−1.09	1476	1447	+ 6	−23	30 17	690+0.58	698		+ 8	
24 49	1419−1.09	1436	1406	+17	−13	39 6	864+0.76	891		+27	
26 54	1365−1.09	1386	1356	+21	− 9	42 11	931+0.80	957		+46	
28 54	1315−1.08	1317	1288	+ 2	−27	51 6	1136+0.89	1197		+61	
31 45	1245−1.07	1253		+ 8		53 5	1184+0.91	1277		+93	
35 10	1162−1.06	1157		− 5		54 40	1222+0.92	1285		+63	
37 32	1104−1.05	1097		− 7		1 14 54	1731+0.99	1795	1780	+64	+49
38 54	1072−1.04	1037		−35		16 58	1782+0.99	1835	1823	+53	+41
46 5	910−1.00	891		−19		18 25	1821+1.00	1895	1889	+74	+68
48 31	857−0.98	838		−19		21 3	1887+1.00	$1955-\alpha_2$		$+67-\alpha_2$	+67
0 6 26	562−0.53	578		+16							

Here, it is evident, the observed distances are systematically too great for the mean phases, and it is impossible to satisfactorily eliminate this error in the way we have generally adopted in the case of these eclipses, because there is a gap near the beginning of the eclipse, corresponding to the best observations near the end, while the gap between $0^h\ 55^m$ and $1^h\ 14^m$ corresponds to the best series near the beginning. The systematic error in question seems to be zero, or even negative, near the middle of the eclipse. Under these circumstances, our best course seems to be to correct the observed distances by an empirical formula, and to give most weight to the observations near the extreme phases. We choose the correction,

$$\delta D = -30'' \left\{ 1 - \left(\frac{D - 1400}{555} \right)^2 \right\},$$

by applying which we form the second column of observed distances and of correction to the tabular distances. Where this second column is not formed, we have corresponding observations before and after the middle of the eclipse.

Commencing now with the consideration of the contacts, the considerable magnitude of the eclipse at the observed moment of contact renders it suspicious; still, as

HEVELIUS says, it was observed "accuratissimé", I have not felt justified in rejecting it. Combining the observations of first and last contacts in the usual manner, we find:—

$$\delta\varepsilon + 33'', \text{ wt.} = 2.$$

The mean of the seven observations following first contact, using the corrected distances, gives

$$\delta\varepsilon = + 26'', \text{ wt.} = 1.$$

The mean of the three observations preceding last contact gives

$$\delta\varepsilon = + 53'', \text{ wt.} = 2.$$

The result of the intermediate observations, five on each side of the middle of the eclipse, in which the distance exceeds 890″, formed by taking the differences of the corresponding measures on each side, is:—

$$\delta\varepsilon + 36'', \text{ wt.} = 3;$$

the mean result of all the measures,

$$\delta\varepsilon = + 38''.$$

Considering the uncertainty of the times and of the measures, the probable error of this result cannot be much below 10″.

Eclipse of 1654, *August* 11, *observed by* WALTERIUS *at Aix.*

Moon's semi-diameter at beginning . 970″
Moon's semi-diameter at end . . . 973″
Sun's semi-diameter . . . . 948″

Obs. Alt. of ⊙.	Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Δ	Obs. Alt. of ⊙.	Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Δ
° ′	h m	′	′	′	° ′	h m	′	′	′
35 30	20 24.9	$32.0 - 1.00\delta\varepsilon$	$32.0 - a_1$	0.0	51 10	22 1.1	$15.6 + 0.78\delta\varepsilon$	16.2	+ 0.6
36 15	20 29.3	30.2 − 0.99	29.3	− 0.9	52 2	22 7.2	17.1 + 0.86	17.5	+ 0.4
38 35	20 42.7	25.3 − 0.94	24.1	− 1.2	52 26	22 10.1	18.0 + 0.89	18.8	+ 0.8
39 45	20 49.5	22.8 − 0.89	22.8	0.0	53 12	22 15.6	19.5 + 0.94	20.2	+ 0.7
41 10	20 57.8	20.0 − 0.82	21.5	+ 1.5	53 50	22 20.6	21.1 + 0.97	21.5	+ 0.4
41 35	21 0.3	18.3 − 0.80	18.8	+ 0.5	54 21	22 24.7	22.4 + 1.00	22.8	+ 0.4
42 35	21 6.2	17.4 − 0.72	17.5	+ 0.1	54 55	22 29.2	23.9 + 1.02	24.1	+ 0.2
43 6	21 9.3	16.5 − 0.67	16.2	− 0.3	55 20	22 32.7	25.1 + 1.03	25.5	+ 0.4
45 35	21 24.3	13.2 − 0.32	13.6	+ 0.4	55 33	22 34.5	25.7 + 1.04	26.8	+ 1.1
47 14	21 34.9	12.2 + 0.04	12.3	+ 0.1	55 58	22 38.0	26.8 + 1.05	28.1	+ 1.3
48 10	21 40.9	12.4 + 0.25	10.9	− 1.5	56 18	22 41.0	27.9 + 1.05	29.4	+ 1 5
49 7	21 47.2	13.0 + 0.46	13.6	+ 0.6	57	22 47.4	30.1 + 1.07	30.7	+ 0.6
50 20	21 55.3	14.3 + 0.66	14.9	+ 0.6	57 20	22 50.4	31.2 + 1.07	$32.0 - a_2$	+ 0.8

There is no evidence of systematic error in the determination of the phases. If we take the sum of all the equations in which the coefficient exceeds 0.6, the contacts excepted, we have:—

Sum of seven equations near beginning	$5.83\,\delta\varepsilon =$	$0'.3$
Sum of thirteen equations near end . .	12.36	$9'.0$
Sum of all	18.19	$9'.3$.

From which we find $\delta\varepsilon = +0'.51$. Supposing $\alpha_2 = \frac{1}{2}\alpha_1$, the contacts alone will give $\delta\varepsilon = +0'.53$. We may therefore put, as the result of this eclipse,

$$\delta\varepsilon = +31''.$$

Eclipse of 1661, *March* 29–30, *observed by* HEVELIUS.

Moon's apparent semi-diameter at beginning .	$1006''.0$
Moon's apparent semi-diameter at end . . .	$1006''.5$
Sun's apparent semi-diameter	$959''.9$

Local Mean Time.			Tabular Dist. of Centres.	Observed Distance.	Corr. to Tab. Dist.	Local Mean Time.			Tabular Dist. of Centres.	Observed Distance.	Corr. to Tab. Dist.
h	m	s	"	"	"	h	m	s	"	"	"
22	19	10	$1991 - 1.03\,\delta\varepsilon$	$1966 - a_1$	− 25	23	53	47	$1014 + 0.88\,\delta\varepsilon$	967	− 47
	20	33	1954 − 1.03	1926	− 28	0	4	39	1235 + 0.99	1247	+ 12
	21	1	1944 − 1.02	1906	− 38		6	25	1274 + 1.00	1307	+ 33
	22	51	1903 − 1.02	1866	− 37		8	12	1312 + 1.02	1367	+ 55
	24	16	1866 − 1.01	1826	− 40		15	12	1472 + 1.05	1527	+ 55
	25	39	1829 − 1.01	1796	− 33		16	20	1498 + 1.06	1547	+ 49
	27	24	1784 − 1.00	1746	− 38		17	50	1533 + 1.06	1567	+ 34
	30	24	1706 − 0.99	1686	− 20		19	4	1561 + 1.07	1607	+ 46
	41	30	1438 − 0.93	1447	+ 9		19	9	1579 + 1.07	1627	+ 48
	50	19	1236 − 0.86	1267	+ 31		20	34	1596 + 1.07	1637	+ 41
	58	59	1054 − 0.75	1067	+ 13		22	4	1632 + 1.07	1667	+ 35
	59	55	1035 − 0.74	1027	− 8		22	58	1654 + 1.08	1687	+ 33
23	1	40	1003 − 0.71	997	− 6		23	48	1674 + 1.08	1707	+ 33
	2	36	988 − 0.70	947	− 41		25	6	1705 + 1.08	1727	+ 22
	4	32	955 − 0.65	907	− 48		26	7	1730 + 1.08	1767	+ 37
	9	2	878 − 0.54	847	− 31		26	45	1745 + 1.08	1787	+ 42
	12	8	837 − 0.46	837	0		27	56	1774 + 1.09	1807	+ 33
	13	22	824 − 0.42	827	+ 3		28	53	1798 + 1.09	1847	+ 49
	19	14	758 − 0.22	747	− 11		30	21	1832 + 1.10	1886	+ 54
	21	18	744 − 0.15	727	− 17		33	26	1907 + 1.10	$1966 - a_2$	+ 59
	40	41	809 + 0.61	827	+ 18						

Combining the seven phases following the beginning with the corresponding ones preceding the end, we find $\delta\varepsilon = +34''$. The contacts alone give $\delta\varepsilon = +48''$. Giving the mean result from contacts the weight of two pairs of observations of phase, we have:—

$$\delta\varepsilon = +37''.$$

The other phases do not correspond to each other, and the agreement of the seven pairs we have used is so good that it does not seem necessary to discuss them.

Eclipse of 1666, *July* 1, *observed by* HEVELIUS.

Moon's apparent semi-diameter at beginning . 944″.8
Moon's apparent semi-diameter at end . . . 949″.9
Sun's apparent semi-diameter . . . . 944″.6

Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tab. Dist.	Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tab. Dist.
h m s	″	″	″	h m s	″	″	″
19 1 17	$1904 - 0.92\delta\varepsilon$	$1889 - a_1$	$-15 - a_1$	19 59 24	$614 - 0.15\delta\varepsilon$	585	− 29
3 17	1849 − 0.91	1830	− 19	20 1 32	602 − 0.07	574	− 28
6 10	1770 − 0.90	1772	+ 2	4 52	587 + 0.09	582	− 5
8 17	1711 − 0.90	1713	+ 2	12 17	617 + 0.39	602	− 15
10 37	1649 − 0.89	1654	+ 5	17 12	667 + 0.57	672	+ 5
16 44	1487 − 0.87	1516 :	+ 29 :	23 17	760 + 0.72	751	− 9
20 46	1383 − 0.86	1359	− 24	25 28	798 + 0.76	791	− 7
23 37	1311 − 0.84	1300	− 11	33 55	958 + 0.86	966	+ 8
27 22	1216 − 0.82	1201	− 15	36 1	1001 + 0.88	1027	+ 26
29 30	1163 − 0.80	1155	− 8	42 12	1134 + 0.92	1145	+ 11
33 40	1065 − 0.77	1064	− 1	49 6	1285 + 0.95	1322	+ 37
37 37	971 − 0.73	946	− 25	51 59	1354 + 0.95	1381	+ 27
42 42	866 − 0.65	829	− 37	53 19	1385 + 0.96	1422	+ 37
43 52	841 − 0.63	799	− 42	20 56 44	1466 + 0.96	1461	− 5
45 32	813 − 0.60	769	− 44	21 0 2	1544 + 0.97	1539	− 5
48 17	754 − 0.54	739	− 15	4 11	1644 + 0.98	1676	+ 32
49 53	729 − 0.49	711	− 18	5 22	1673 + 0.98	1716	+ 43
51 47	702 − 0.44	684	− 18	7 25	1721 + 0.98	1761	+ 40
54 12	667 − 0.36	632	− 35	9 7	1761 + 0.98	1815	+ 54
57 2	636 − 0.25	602	− 34	21 12 40	1849 + 0.99	$1894 - a_2$	$+45 - a_2$

The contacts alone here give

$$\delta\varepsilon = +36''.$$

The four observations following first contact, combined with the corresponding four preceding last contact, give

$$\delta\varepsilon = +24.$$

The remaining observations in which the distance exceeded 900″ give

$$\delta\varepsilon = +22'', \text{ or } \delta\varepsilon = +15'',$$

according as we include or reject the doubtful fifth observation of phase. The most probable result of all the observations is,

$$\delta\varepsilon = +25''.$$

Eclipse of 1676, *June* 10, *observed by* FLAMSTEED *at Greenwich.*

Moon's apparent semi-diameter at first observation	.	894″.9
Moon's apparent semi-diameter at last observation	.	896″.0
Sun's semi-diameter	. . . .	945″.0

Mean Time.	Tabular Dist. of Centres.	Observed Dist. (by cusps).	Corr. to Tabular Dist.
h m s	″	″	″
19 56 16	1751 − 0.66 $\delta\varepsilon$	1736	− 15
20 2 4	1655 − 0.64	1639	− 16
20 11 32	1513 − 0.61	1495	− 18
20 38 19	1244 − 0.22	1282	+ 38
		(by dir. meas.)	
20 16 29	1447 − 0.55 $\delta\varepsilon$	1433	− 14
20 18 58	1416 − 0.53	1411	− 5
20 25 53	1339 − 0.46	1361	+ 22
20 26 53	1329 − 0.45	1308	− 21
20 33 4	1277 − 0.38	1281	+ 4

An examination of FLAMSTEED's observed semi-diameters of the sun shows that his micrometer measures of that element require a correction of −7″.5 for irradiation when the long telescope was used, and −14″.3 when the short one was used. These corrections have been applied in the column of observed distance when necessary.

At the time of the last measure of the distance of cusps, the eclipse was so far advanced that no reliable result could be obtained from the measure. Moreover, the discordance of the result is such as to indicate some mistake. The results from the other measures may fairly receive the respective weights 4, 3, and 2. The discordance of the third measure of phase is also so great as to give rise to a suspicion of some error in the record. The error is in fact between 30″ and 40″, whereas the probable error of FLAMSTEED's measures of the sun's semi-diameter does not in general exceed 3″ or 4″.

From the three first measures of distance of cusps with the weights assigned, we have,

$$\delta\varepsilon = +\,25''.0.$$

The sum of all the equations given by the phases is,

$$2.37\,\delta\varepsilon = +\,14''; \;\therefore\; \delta\varepsilon = +\,6''.$$

Rejecting the third measure, we shall have,

$$1.91\,\delta\varepsilon = +\,36; \;\therefore\; \delta\varepsilon = +\,19''.$$

The results from measures of distance of cusps near the beginning of an eclipse ought to be pretty accurate, while the discordance of the measures of phase renders their results uncertain. I therefore consider the most probable result from this eclipse to be,

$$\delta\varepsilon = +\,23'' \pm 6''.$$

Eclipse of 1684, *July* 12, *observed by* FLAMSTEED.

Moon's apparent semi-diameter at beginning . 946″.7
Moon's apparent semi-diameter at end . . . 943″.8
Sun's semi-diameter . . . . 944″.6

Mean time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.	Mean time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.
h m s	″	″	″	h m s	″	″	″
2 17 44	1891 − 0.96 $\delta\varepsilon$	1862	− 29	3 39 35	786 + 0.26 $\delta\varepsilon$	797	+ 11
28 39	1654 − 0.94	1655	+ 1	41 54	811 + 0.33	826	+ 15
42 59	1352 − 0.90	1334*	− 18	46 21	865 + 0.43	885	+ 20
47 56	1252 − 0.87	1241	− 11	50 39	931 + 0.53	944	+ 13
3 1 42	997 − 0.75	1005	+ 8	53 4	973 + 0.57	1003	+ 30
5 24	937 − 0.70	945	+ 8	59 17	1087 + 0.66	1121	+ 34
6 23	923 − 0.69	901*	− 22	4 2 19	1148 + 0.70	1180	+ 32
8 6	899 − 0.66	869*	− 30	5 5	1205 + 0.72	1240	+ 35
8 34	891 − 0.65	886	− 5	12 52	1377 + 0.78	1417	+ 40
14 2	821 − 0.54	827	+ 6	20 28	1556 + 0.83	1568†	+ 12
18 7	781 − 0.45	744*	− 37	20 40	1561 + 0.83	1594	+ 33
19 19	770 − 0.42	768	− 2	23 34	1632 + 0.84	1640†	+ 8
21 59	754 − 0.33	724*	− 30	25 56	1690 + 0.85	1741	+ 51
26 10	736 − 0.19	738	+ 2	26 52	1714 + 0.85	1736†	+ 22
30 13	734 − 0.04	738	+ 4	29 26	1778 + 0.86	1829	+ 51
36 27	763 + 0.15	768	+ 5	32 42	1859 + 0.87	1888	+ 29

* Micrometer measures of "pars lucida". † From measures of cusps.

There is clearly a systematic error in the measures of phase, rendering it necessary to compare phases as nearly equal as possible on each side of the middle. This comparison gives the equations,

$$\begin{array}{llcll} 0.87\,\delta\varepsilon = & 9'', & & 1.32\,\delta\varepsilon = & 22'' \\ 1.08 & 25 & & 1.59 & 46 \\ 1.23 & 5 & & 1.78 & 43 \\ & & & 1.81 & 80. \end{array}$$

The solution of these equations gives

$$\delta\varepsilon = + 25''.$$

The micrometer measures of "pars lucidae" before the middle of the eclipse give

$$\delta\varepsilon = + 38''.$$

The three measures of cusps near the end give

$$\delta\varepsilon = + 17''.$$

The most probable result from all the observations is

$$\delta\varepsilon = + 24'' \pm 4''.$$

Eclipse of 1684, *July* 12, *observed by* LA HIRE *at Paris.*

Moon's apparent semi-diameter at beginning . 946″.7
Moon's apparent semi-diameter at end . . . 943″.2
Sun's semi-diameter . . . . 944″.6

Local Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.	Local Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.
h m s	″	″	″	h m s	″	″	″
2 30 23	$1934.8 - 0.98\,\delta\varepsilon$	1891.3	$-43-a_1$	4 18 57	$1139.1 + 0.73\,\delta\varepsilon$	1173	+ 34
35 16	1828.1 − 0.97	1798	− 30	23 37	1244.4 + 0.77	1284	+ 40
41 6	1699.4 − 0.96	1673	− 26	29 57	1393.8 + 0.82	1417	+ 23
43 16	1652.0 − 0.96	1635	− 17	36 57	1566.5 + 0.84	1607	+ 40
49 16	1521.0 − 0.95	1497	− 24	43 37	1736.6 + 0.87	1778	+ 41
53 6	1438.6 − 0.94	1418	− 21	48 27	1862.8 + 0.89	1887.8	$+25-a_2$
56 46	1359.9 − 0.93	1325	− 35			From meas. of cusps.	
3 3 6	1227.0 − 0.90	1196	− 31				
9 16	1102.3 − 0.87	1077	− 25	2 37 36	$1776.4 - 0.97\,\delta\varepsilon$	1707	− 69
15 46	979.1 − 0.81	975	− 4	45 6	1611.8 − 0.96	1587	− 25
23 6	852.9 − 0.71	841	− 12	54 26	1409.6 − 0.93	1394	− 16
26 26	803.2 − 0.65	784	− 19	59 36	1299.8 − 0.92	1301	+ 1
33 26	719.1 − 0.49	708	− 11	3 7 6	1145.8 − 0.88	1081	− 65
41 26	669.0 − 0.22	660	− 9	12 51	1032.6 − 0.83	1025	− 8
45 6	666.2 − 0.08	665	− 1	4 21 37	1198.4 + 0.76	1229	+ 31
56 7	736.4 + 0.32	765	+ 29	25 57	1298.4 + 0.79	1331	+ 33
4 1 47	811.6 + 0.47	825	+ 13	33 18	1475.4 + 0.83	1502	+ 27
5 27	871.0 + 0.55	879	+ 8	42 27	1706.6 + 0.87	1727	+ 20
10 7	956.0 + 0.63	975	+ 19				

Treating the contacts in the usual way, the result is,

$$\delta\varepsilon = +31''.$$

The sum of the eleven equations from phases following first contact in which the coefficient of $\delta\varepsilon$ exceeds 0.5 is,

$$9.65\,\delta\varepsilon = 244''; \;\therefore\; \delta\varepsilon = +25''.$$

The sum of seven phases preceding last contact,

$$5.21\,\delta\varepsilon = 205''; \;\therefore\; \delta\varepsilon = +40''.$$

The measures of cusps near beginning, giving double weight when $D > 1600''$, give the result,

$$\delta\varepsilon = +37''.$$

Those near end give

$$\delta\varepsilon = +32''.$$

The most probable mean result is,

$$\delta\varepsilon = +32'' \pm 2''.$$

Eclipse of 1687, *May* 11, *observed by* FLAMSTEED.

Moon's apparent semi-diameter at beginning . 955″.4
Moon's apparent semi-diameter at end . . . 954″.3
Sun's apparent semi-diameter . . . . 944″.6

Mean Time.	Tabular Distance of Centres.	Observed Distance.	Mean Time.	Tabular Distance of Centres.	Observed Distance.
h *m* *s*	″	″	*h* *m* *s*	″	″
1 13 3	1905	. .	1 38 43	1812 + 0.11 $\delta\varepsilon$ + 0.99 $i\delta\theta$	1804.8
15 41	1885 − 0.18 $\delta\varepsilon$ + 0.98 $i\delta\theta$	1871.2	40 49	1813 + 0.13 + 0.99	1807.4
17 9	1877 − 0.17 + 0.98	1859.7	44 47	1820 + 0.19 + 0.98	1816.7
22 5	1849 − 0.11 + 0.99	1834.2	48 3	1830 + 0.23 + 0.97	1832.0
28 31	1825 − 0.02 + 0.99	1816.7	54 1	1855 + 0.30 + 0.95	1858.9
31 53	1817 0.00 + 1.00	1810.5	55 43	1864 + 0.32 + 0.95	1870.3
35 27	1812 + 0.07 + 0.99	1804.9	2 0 13	1892 + 0.38 + 0.93	1898.9 − a_2
38 3	1812 + 0.10 + 0.99	1804.8	0 17	1893 + 0.38 + 0.93	1898.9 − a_2

This eclipse and the next one were originally computed with the hope that they would give a valuable correction to the longitude of the moon's node. They are too small to be of any use for determining the longitude. But it seems that in the two eclipses a change in the node will have the same effect on the distance of centres, and the systematic errors in the observations may be such that no good result can be obtained. I therefore make no use of the eclipses, but present the data for the use of any investigator who may choose to discuss them.

Eclipse of 1689, *September* 13, *observed by* FLAMSTEED.

Moon's apparent semi-diameter at beginning . 923″.0
Moon's apparent semi-diameter at end . . . 920″.4
Sun's apparent semi-diameter . . . . 955″.8

Mean Time.	Tabular Distance of Centres.	Observed Distance.	Mean Time.	Tabular Distance of Centres.	Observed Distance.
h *m* *s*	″	″	*h* *m* *s*	″	″
3 24 57	1884 − 0.34 $\delta\varepsilon$ + 0.90 $i\delta\theta$	1843.4 − a_1	4 8 57	1693 + 0.26 $\delta\varepsilon$ + 0.93 $i\delta\theta$	1701.3
37 7	1762 − 0.20 + 0.94	1764.0	11 35	1706 + 0.30 + 0.92	1712.5
40 17	1736 − 0.16 + 0.95	1727.5	15 39	1732 + 0.34 + 0.90	1740.1
44 43	1708 − 0.09 + 0.96	1703.7	18 57	1759 + 0.39 + 0.88	1763.1
48 37	1691 − 0.04 + 0.96	1687.9	21 39	1784 + 0.43 + 0.86	1792.9
53 51	1676 + 0.04 + 0.96	1676.1	24 21	1810 + 0.45 + 0.85	1818.1
4 3 57	1676 + 0.19 + 0.95	1674.3	28 57	1863 + 0.49 + 0.82	1876.2 − a_2
7 5	1686 + 0.24 + 0.94	1685.0	29 3	1864 + 0.50 + 0.81	1876.2 − a_2

Eclipse of 1699, *September* 22, *observed by* LA HIRE *at Paris.*

Moon's semi-diameter at beginning . 963″.5
Moon's semi-diameter at end . . . . 966″.5
Sun's semi-diameter . . . . 958″.4

Paris Mean Time.			Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.	Paris Mean Time.			Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.
h	m	s	″	″	″	h	m	s	″	″	″
20	7	9	$1936.2-1.01\,\delta\varepsilon$	1921.9	$-14.3-a_1$	21	22	48	$388.4+0.26\,\delta\varepsilon$	406.3	+17.9
	9	34	1872.3−1.01	1842.1	−30.2		29	44	450.2+0.63	486.3	+36.1
	12	19	1800.0−1.01	1762.3	−37.7		35	30	538.9+0.80	566.2	+27.3
	16	10	1699.3−1.00	1682.5	−16.8		39	28	611.4+0.88	646.1	+34.7
	19	21	1616.4−1.00	1602.7	−13.7		43	18	687.2+0.91	726.0	+38.8
	22	35	1532.9−1.00	1522.9	−10.0		49	33	818.3+0.97	885.9	+67.6
	24	37	1480.7−0.99	1443.2	−37.5		54	7	918.0+0.99	965.9	+47.9
	28	10	1390.3−0.98	1363.4	−26.9		58	4	1005.4+1.00	1045.8	+40.4
	30	57	1320.1−0.98	1283.6	−36.5	22	2	56	1115.2+1.01	1125.7	+10.5
	33	55	1245.4−0.97	1203.9	−41.5		6	38	1199.3+1.02	1205.6	+ 6.3
	37	7	1166.0−0.96	1124.1	−41.9		9	46	1270.9+1.03	1285.5	+14.6
	40	46	1076.7−0.95	1044.3	−32.4		12	57	1344.4+1.03	1365.5	+21.1
	44	19	991.4−0.93	964.6	−26.8		16	56	1435.3+1.03	1445.4	+10.1
	47	53	906.7−0.91	884.8	−21.9		29:	55	1504.0+1.04	1525.3	+21.3
	51	14	829.1−0.89	805.0	−24.1		24	17	1604.8+1.04	1605.3	+ 0.5
	55	11	740.6−0.85	725.2	−15.4		27	44	1684.4+1.04	1685.2	+ 0.8
	59	2	658.2−0.80	645.5	−12.7		31	10	1763.7+1.04	1765.1	+ 1.4
21	3	3	578.0−0.72	565.7	−12.3		33	48	1824.6+1.04	1845.0	+20.4
	7	57	491.9−0.59	486.0	− 5.9		37	9	1901.8+1.04	1924.9	$+23.1-a_2$
	15	17	402.5−0.23	406.2	+ 3.7						

The contacts give

$$\delta\varepsilon = + 20''.2.$$

The 16 measures of phase following first contact,

$$15.23\ \delta\varepsilon = 426''; \ \therefore \delta\varepsilon = + 27''.9.$$

The 16 measures of phase preceding last contact,

$$15.87\ \delta\varepsilon = 364''; \ \therefore \delta\varepsilon = + 22''.9.$$

The mean result is,

$$\delta\varepsilon = + 24''.8 \pm 2''.$$

Eclipse of 1706, *May* 11, *observed by* LA HIRE *at Paris.*

Moon's apparent semi-diameter at beginning . 1003″.0
Moon's apparent semi-diameter at end . . . 1006″.3
Sun's apparent semi-diameter . . . . 949″.1

Paris Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.	Paris Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.
h m s	″	″	″	h m s	″	″	″
20 21 47	1959.0 − 1.08 $\delta\varepsilon$	1932:	− 27	21 50 8	670.4 + 1.12 $\delta\varepsilon$	702	+ 32
44 37	1275.0 − 1.06	1254	− 21	51 23	703.6 + 1.12	740	+ 36
48 37	1157.8 − 1.05	1124	− 34	52 48	741.4 + 1.12	778	+ 37
51 37	1070.4 − 1.05	1048	− 22	54 23	783.9 + 1.12	822	+ 38
54 12	995.5 − 1.04	972	− 24	56 8	830.4 + 1.13	860	+ 30
56 58	915.9 − 1.03	896	− 20	57 28	866.9 + 1.13	897	+ 30
57 48	892.1 − 1.03	739	(−153)	59 3	909.3 + 1.13	936	+ 27
21 3 53	719.9 − 0.99	701	− 19	22 0 23	945.2 + 1.13	974	+ 29
5 18	680.5 − 0.98	663	− 27	1 53	985.7 + 1.13	1012	+ 26
6 33	645.9 − 0.97	625	− 21	3 23	1026.2 + 1.13	1050	+ 24
7 48	611.3 − 0.96	587	− 24	5 3	1071.4 + 1.13	1088	+ 17
9 18	570.4 − 0.95	549	− 21	6 23	1107.3 + 1.13	1125	+ 18
10 48	530.4 − 0.93	511	− 19	7 58	1150.3 + 1.13	1163	+ 13
12 10	494.3 − 0.91	473	− 21	9 28	1190.9 + 1.13	1202	+ 11
13 48	452.0 − 0.88	435	− 17	10 38	1222.5 + 1.13	1240	+ 18
15 11	417.3 − 0.85	398	− 19	11 33	1247.2 + 1.13	1278	+ 31
17 3	372.3 − 0.79	360	− 12	12 48	1281.1 + 1.13	1315	+ 34
18 43	333.9 − 0.72	322	− 12	14 33	1328.4 + 1.13	1354	+ 26
20 43	292.2 − 0.62	284	− 8	15 46	1361.3 + 1.13	1392	+ 31
22 43	256.6 − 0.44	246	− 11	17 28	1407.3 + 1.13	1430	+ 23
27 38	214.0 + 0.20	221	+ 7	18 53	1445.6 + 1.13	1468	+ 22
30 53	233.0 + 0.62	246	+ 13	21 53	1526.7 + 1.13	1544	+ 17
32 53	260.8 + 0.80	284	+ 23	23 3	1558.1 + 1.13	1587	+ 29
35 4	300.5 + 0.91	322	+ 22	24 30	1597.0 + 1.13	1625	+ 28
36 38	333.2 + 0.97	360	+ 27	25 48	1632.0 + 1.13	1663	+ 31
38 16	369.8 + 1.01	398	+ 28	26 58	1663.4 + 1.13	1701	+ 38
39 38	401.7 + 1.06	436	+ 34	28 10	1695.7 + 1.13	1739	+ 43
41 18	442.3 + 1.06	474	+ 32	29 43	1737.3 + 1.13	1777	+ 40
42 58	483.8 + 1.07	512	+ 28	31 14	1778.1 + 1.13	1815	+ 37
44 8	513.6 + 1.08	550	+ 36	32 43	1817.8 + 1.13	1853	+ 35
45 43	554.4 + 1.08	588	+ 34	34 18	1860.2 + 1.13	1891	+ 31
47 3	589.1 + 1.10	626	+ 37	37 2	1933.5 + 1.13	1955	+ 22 − a_2
48 38	630.8 + 1.11	664	+ 33				

As there is a gap of 23 minutes in the observations after the beginning, we have, during this interval, no observations to compare with the corresponding ones near the end. The sum of the 14 equations after the beginning is,

$$13.65\ \delta\varepsilon = 309''; \ \therefore\ \delta\varepsilon = +22''.6$$

The sum of 24 equations most nearly corresponding to them after the middle is,

$$26.45\ \delta\varepsilon = 675''; \ \therefore\ \delta\varepsilon = +25''.5.$$

The remaining phases near the end which have none to correspond to them near the beginning would give

$$\delta\varepsilon = +27''.4.$$

I think this result should be rejected, and that we should take, as the result of the observation,

$$\delta\varepsilon = +24''.1 \pm 2''.$$

Eclipse of 1715, *May* 2, *observed by the* Messrs. LA HIRE *at Paris.*

Moon's apparent semi-diameter at beginning . 1007″.5
Moon's apparent semi-diameter at end . . . 1011″.2
Sun's apparent semi-diameter . . . . . . 951″.2

LA HIRE, the father, using new micrometer.				LA HIRE, the son, using image on screen.			
Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.	Local Mean Time.	Tabular Dist. of Centres.	Observed Distance.	Corr. to Tabular Dist.
h m s	″	″	″	h m s	″	″	″
20 9 0	1971.6 − 1.15 $\delta\varepsilon$	1958.7 − a_1	− 12.9	20 9 0	1971.6 − 1.15 $\delta\varepsilon$	1958.7 − a_1	− 12.9
14 9	1813.9 − 1.15	1800.3	− 13.6	14 6	1810.4 − 1.15	1800.3	− 10.1
19 34	1649.5 − 1.15	1641.9	− 7.6	16 56	1729.2 − 1.15	1721.1	− 8.1
24 38	1496.8 − 1.15	1483.5	− 13.3	19 26	1653 5 − 1.15	1641.9	− 11.6
29 9	1361.7 − 1.15	1325.1	− 36.6	21 52	1579.9 − 1.15	1562.7	− 17.2
33 4	1245.4 − 1.15	1245.9	+ 0.5	24 40	1495.7 − 1.15	1483.5	− 12.2
38 20	1090.0 − 1.15	1087.6	− 2.4	27 33	1409.5 − 1.15	1404.3	− 5.2
40 47	1018.0 − 1.15	1008.5	− 9.5	30 11	1330.8 − 1.15	1325.1	− 5.7
43 29	939.2 − 1.15	929.2	− 10.0	33 1	1246.8 − 1.15	1245.9	− 0.9
46 0	866.3 − 1.15	850.0	− 16.3	35 19	1178.8 − 1.15	1166.7	− 12.1
48 50	784.6 − 1.15	770.9	− 13.7	37 58	1100.6 − 1.15	1087.6	− 13.0
51 40	703.7 − 1.14	691.7	− 12.0	40 56	1013.4 − 1.15	1008.5	− 4.9
54 14	631.1 − 1.13	612.5	− 18.6	45 47	872.5 − 1.15	850.0	− 22.5
56 48	559.9 − 1.12	533.3	− 26.6	49 7	776.4 − 1.15	770.9	− 5.5
21 0 12	467.0 − 1.11	454.1	− 12.9	52 14	687.6 − 1.14	691.7	+ 4.1
3 16	386.1 − 1.06	374.9	− 11.2	21 3 50	371.6 − 1.05	374.9	+ 3.3
6 24	308.1 − 0.90	295.7	− 12.4	6 38	302.6 − 0.87	295.7	− 6.9
12 4	197.1 − 0.58	208.9	+ 11.8	11 11	209.9 − 0.69	216.7	+ 6.8
18 44	201.6 + 0.50	190.3	− 11.3	15 37	175.4 + 0.02	216.8	+ 41.4
22 44	276.3 + 0.81	296.0	+ 19.7	22 10	264.0 + 0.78	296.0	+ 32.0
25 44	344.7 + 0.92	375.3	+ 30.6	25 51	349.0 + 0.92	375.4	+ 26.4
32 15	512.0 + 1.03	533.9	+ 21.9	28 59	427.5 + 0.99	454.8	+ 27.3
35 26	596.7 + 1.04	613.2	+ 16.5	32 0	506.2 + 1.03	534.1	+ 27.9
39 8	696.3 + 1.07	692.5	− 3.8	35 24	596.3 + 1.04	613.4	+ 17.1
41 30	760.2 + 1.08	771.8	+ 11.6	38 31	680.1 + 1.06	692.8	+ 12.7
44 54	852.5 + 1.09	851.2	− 1.3	41 14	753.4 + 1.08	772.1	+ 18.7
47 34	925.2 + 1.10	930.6	+ 5.4	44 32	842.8 + 1.09	851.5	+ 8.7
50 44	1011.1 + 1.10	1010.2	− 0.9	47 36	926.1 + 1.10	930.9	+ 4.8
53 35	1088.5 + 1.10	1089.7	+ 1.2	50 24	1002.1 + 1.10	1010.3	+ 8.2
56 6	1157.1 + 1.11	1169.2	+ 12.1	53 27	1084.9 + 1.10	1089.6	+ 4.7
58 54	1233.0 + 1.11	1248.5	+ 15.5	56 47	1174.6 + 1.11	1169.0	− 5.6
22 5 16	1404.9 + 1.12	1407.0	+ 2.1	59 34	1251.1 + 1.11	1248.3	− 2.8
8 58	1504.5 + 1.12	1486.8	− 17.7	22 2 44	1336.8 + 1.12	1327.7	− 9.1
11 56	1566.4 + 1.12	1566.0	− 0.4	5 36	1413.9 + 1.12	1407.0	− 6.9
13 53	1636.7 + 1.12	1645.1	+ 8.4	8 45	1498.7 + 1.12	1486.4	− 12.3
19 12	1779.2 + 1.12	1803.8	+ 24.6	14 12	1645.1 + 1.12	1645.1	0.0
22 17	1861.6 + 1.13	1883.1	+ 21.6	19 14	1780.0 + 1.12	1803.8	+ 23.8
25 31	1947.8 + 1.13	1962.4 − a_2	+ 14.7	25 29	1946.9 + 1.13	1962.4 − a_2	+ 15.5

The 16 measures of the father, following first contact, give	$\delta\varepsilon = +12''.0$
His 18 measures preceding last contact	$\delta\varepsilon = +\ 8''.8$
The 16 observations of the son following first contact .	$\delta\varepsilon = +\ 7''.1$
His 18 observations preceding last contact	$\delta\varepsilon = +\ 9''.2$
Contacts observed by the father	$\delta\varepsilon = +14''.1$
Contacts observed by the son	$\delta\varepsilon = +14''.6.$

The contacts noted by the two observers agree so well that there is a suspicion of their not being independent. The correspondence between the considerable errors of the three phases preceding last contacts might give rise to a similar suspicion respecting the observations of phase, but this correspondence does not seem to extend through the observations.

Giving the combined results from measures of phase four times the weight of those from contacts, we shall have

$$\delta\varepsilon = +10''.3 \pm 1''.5.$$

Eclipse of 1715, *May* 2, *observed by* CASSINI *at Marly.*

$\phi = 48^\circ\ 51'.7$; $\lambda = 8^m\ 24^s$ east from Greenwich.

The local mean times are taken without correction from the Memoirs of the Academy for 1715, pp. 83, 84, applying -- $3^m\ 22^s$ for equation of time.

Local Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.	Local Mean Time.	Tabular Distance of Centres.	Observed Distance.	Corr. to Tab. Dist.
h m s	$''$	$''$	$''$	h m s	$''$	$''$	$''$
20 7 40	$1976.4 - 1.15\delta\varepsilon$	$1959 - a_1$	$-17 - a_1$	21 14 8	169.4	177	+ 8
12 18	1835.2 − 1.15	1800	− 35	16 8	180.2	177	− 3
17 6	1688.7 − 1.15	1642	− 47	18 38	214.8	218	+ 3
22 57	1512.1 − 1.15	1484	− 28	24 53	$349.0 + 0.92\delta\varepsilon$	376	+ 27
26 2	1419.8 − 1.15	1405	− 15	30 55	506.8 + 1.03	535	+ 28
29 8	1327.4 − 1.15	1326	− 1	37 54	693.2 + 1.07	693	0
34 15	1175.4 − 1.15	1167	− 8	43 42	849.8 + 1.09	852	+ 2
39 44	1014.5 − 1.15	1009	− 6	55 38	1174.5 + 1.11	1169	− 6
45 28	847.9 − 1.15	850	+ 2	22 8 8	1512.7 + 1.12	1486	− 27
52 2	658.5 − 1.14	692	+ 34	13 38	1660.7 + 1.12	1645	− 16
56 49	526.5 − 1.13	534	+ 7	19 8	1808.3 + 1.12	1803	− 5
21 2 48	366.6 − 1.06	375	+ 8	24 28	1951.7 + 1.13	$1962 - a_2$	$+10 - a_2$
9 18	219.0	217	− 2				

The systematic errors in the estimates of phases are so strongly marked that only corresponding phases can be combined. There are in all eight pairs of such observations, the sum of which give the equation

$$17.66\ \delta\varepsilon = +70''; \ \therefore\ \delta\varepsilon = +4''.$$

The observations of contact alone give

$$\delta\varepsilon = +12''.$$

Owing to the extreme irregularity of the observations of phase, I think the pair of contacts are entitled to as much weight as the whole eight pairs of observations of phase. The result of these observations will then be

$$\delta\varepsilon = +8'' \pm 4''.$$

Eclipse of the Sun, 1715, *May* 2–3, *as observed in England.*

This eclipse was total in England, where a great number of observations were made, the results of which were published in the *Philosophical Transactions*. Unfortunately, in the large majority of cases we have no data whatever for judging of the accuracy with which the time was determined, and the observers are mostly unknown as astronomers. The well-known observers were FLAMSTEED, HALLEY, POUND, and COTES. The latter was so "oppressed by too much company" that he could not observe the first two phases; it may therefore be feared that the same circumstances prevented an exact determination of clock-error. HALLEY, notwithstanding his scientific merits in some directions, seems to have been extremely unskilled in every branch of the art of practical astronomy. POUND made many observations, but there is no way of ascertaining how well his time was determined. FLAMSTEED was the best of the observers, but, unfortunately, his data for clock-error are far from being as certain as is desirable. These uncertainties are especially to be regretted, because the observed times of beginning and end of a total eclipse are not subject to the uncertainties which affect observations of the other phases.

There was, however, one class of determinations made during this eclipse with an accuracy which hardly leaves anything to be desired, and for which we are probably indebted to HALLEY, namely, the limits of the path of totality. We have here the most valuable single datum which astronomy possesses for determining the motion of the moon's node; it is, therefore, very surprising that it should have passed entirely unnoticed and unused.

In discussing this eclipse, we shall begin with the English observations of the times of the total phases, rejecting those of the beginning and end as uncertain in comparison. Last of all, we shall discuss the results of the shadow-limits.

Observations of FLAMSTEED.—Everything accessible respecting these observations is found in the *Historia Coelestis*, vol. ii, p. 551. I have examined the original manuscripts at Greenwich, but find nothing but what is printed. Some light respecting the observations may perhaps be gathered from a letter of FLAMSTEED, printed by BAILY in his *Account of the Rev*[d]. *John Flamsteed*, pp. 315–316. The following are the essential observations, giving times of transit over mural quadrant, and phases of eclipse:—

Date. (Old style.)	Clock Time.			True Apparent Time.			Object.
1715.	*h*	*m*	*s*	*h*	*m*	*s*	
Apr. 21	11	1	7	.	.	.	τ Bootis.
		8	31	.	.	.	η Bootis.
		24	23	.	.	.	κ Virginis.
		30	3	.	.	.	α Bootis.
	20	11	45	20	5	54	Initium Ecl. ☉.
	21	14	41	21	9	0	Totalis obscuratis.
		17	52		12	12	Lux prima.
		19	1		13	21	Venus transit.
	22	25	32	22	19	51	Finis.
26	11	11	28	.	.	.	

The discrepancy of ten seconds in the clock-correction for beginning I cannot certainly explain; it exists in the MS., and may be a correction for phase.

To deduce the clock-corrections from the star-transits, we must know the deviation of the quadrant from the meridian. In KRUEGER's doctoral dissertation, *De Ascensionibus Rectis a Flamsteedio Quadrantis Muralis ope observatis*, Bonn, 1854, is found a discussion of the errors of the quadrant in 1690, in which the following values of m are quoted from a dissertation by ARGELANDER:—

1690, aetate vernali $m = + 26^s.7$
1690, aestate . . $+ 28^s.9$
1699, auctumno . $+ 35^s.8$
1713, mense Junio $+ 69^s.4$.

These are the corrections to reduce the observed time of transit of an equatorial star to the true meridian. Supposing the change to go on, the correction in 1715 would have been about $+ 73^s$. Neglecting, at first, the polar deviation from the meridian, we have the following clock-corrections from the star-transits:—

Date.	Star.	R. A. as computed.	Computed Mean Time of Transit over True Mer.	Clock-corr. minus Deviation.	Dec. of Star.
		h m s	h m s	m s	°
May 2	τ Bootis .	13 33 44	10 52 57	− 8 10	+ 18
	η Bootis .	41 8	11 0 20	− 8 11	+ 19
	κ Virginis .	57 46	16 55	− 7 28	− 9
	α Bootis .	14 2 41	21 49	− 8 14	+ 20
May 7	α Bootis .	2 41	2 9	− 9 19	+ 20

From this it may be concluded that the clock-correction for an equatorial star on May 2 at $11^h.1$ would have been . . . . $-7^m\ 42^s$

Applying ARGELANDER's m negatively . . . . $-1^m\ 13^s$

Clock-error at $11^h.1$ . . . . $-8^m\ 55^s$

Change in 10 hours, daily rate being -13^s . . . . $-\quad 5^s$

Clock-correction for middle of eclipse . . . . $-9^m\ 0^s$.

Another determination of the error of the quadrant has been attempted, as follows:—On 1713, June 16–27, the clock-time of transit of the sun over the true meridian, as derived from morning and afternoon altitudes, was $0^h\ 7^m\ 11^s$, while the transit over the quadrant occurred at $0^h\ 6^m\ 30^s$, showing a correction of $+41^s$. Again, on 1718, August 29–September 9, the true transit was found in the same way to be at $0^h\ 3^m\ 5^s$ clock-time, while the transit over the quadrant was marked at $0^h\ 1^m\ 54^s$. We, therefore, have, for the correction to the quadrant,

1713, at declination $+ 23°$: $c = +0^m\ 41^s$.
1718, at declination $+\ \ 5°$: $c = +1^m\ 11^s$.

The mean declination of the three northern stars observed on May 2 was $+ 19°$, and the uncorrected clock-correction was $-8^m\ 12^s$. The correction of quadrant inter-

polated to this declination is 48^s, making for the true clock-error $-9^m\ 0^s$. If we had taken all four stars, we should have had: mean clock-correction, $-8^m\ 1^s$; mean declination, $+12^\circ$; correction for quadrant, 59^s; and the resulting clock-correction would still be $-9^m\ 0^s$. Correcting, as before, for rate, the correction for the time of the eclipse is $-9^m\ 5^s$.

The correction to apparent time applied by FLAMSTEED is $-5^m\ 40^s$, and the equation of time is $-3^m\ 23^s$, so that the correction actually used by FLAMSTEED, of the derivation of which we have no knowledge, is $-9^m\ 3^s$. We have, then, the three following results for the correction to FLAMSTEED's clock on mean time at the moment of total eclipse:—

Using ARGELANDER's *m* . . . . $-9^m\ 0^s$.
From an independent discussion . . . . $-9^m\ 5^s$.
FLAMSTEED actually used . . . . $-9^m\ 3^s$.

The value of ARGELANDER's *m* resting on an "extrapolation", and its applicability being questionable, not much weight can be given to the first result. I think, therefore, that we may put the clock-correction on mean time at $-9^m\ 4^s$, and that the error can then hardly exceed 3 or 4 seconds.

Observations by HALLEY.—These were made at the rooms of the Royal Society in Crane Court, Fleet Street, London. A re-reduction of his altitudes gives results scarcely differing from those he obtains. The correction of his clock on mean time is $-3^m\ 38^s$. I have assumed his position to be,

$$\varphi = 51^\circ\ 31'$$
$$\lambda = 0^m\ 25^s \text{ west.}$$

The longitude may be some seconds in error, but it would be a useless refinement to discuss it in connection with such observations.

Observations by POUND.—Here we have nothing but apparent times, and can do nothing but apply $-3^m\ 22^s$, the equation of time, to his results. POUND's position was,

$$\varphi = 51^\circ\ 34'$$
$$\lambda = 0^m\ 8^s \text{ east.}$$

Elements derived from Theory.—The Besselian elements of this eclipse are as follows:—

Greenwich Mean Times .	*h m* 19 12	*h m* 20 24	*h m* 21 36	*h m* 22 48	*h m* 24 0
Values of *x*	−1.52076	−0.83934	0.15752	+0.52450	+1.20650
Hourly variation . . .	+0.56762	0.56802	0.56824	0.56810	0.56760
Values of *y*	+0.39727	+0.54586	+0.69408	+0.84170	+0.98870
Hourly variation . . .	+0.12388	0.12367	0.12327	0.12276	0.12223
Log sin *d*	9.42702	9.42742	9.42781	9.42821	9.42860
Radius of penumbra . .	0.53322	0.53333	0.53341	0.53345	0.53343
Radius of shadow . . .	0.01299	0.01288	0.01280	0.01276	0.01268
μ	° ′ ″ 288 50 17.7	° ′ ″ 306 50 29.4	° ′ ″ 324 50 40.8	° ′ ″ 342 50 52.4	° ′ ″ 0 51 3.9

The notation here used is that of § 7. The radii of the penumbra and shadow are those which correspond to the fundamental plane of reference, passing through the

centre of the earth perpendicular to the axis of the shadow. The value of μ is that of μ' corresponding to the meridian of Greenwich.

From these data we obtain the following observed and computed local mean times:—

Place.	Observer.	Total Phase.	Local Mean Time obs.	Local Mean Time comp.	Correction.
			h m s	m s	s
Greenwich .	Flamsteed .	Beginning .	21 5 37	6 34	− 57
		End . . .	21 8 48	9 32	− 44
London . .	Halley . .	Beginning .	21 5 39	6 1	− 22
		End . . .	21 9 2	9 12	− 10
Wanstead .	Pound . .	Beginning .	21 6 6	6 48	− 42
		End . . .	21 9 26	9 52	− 26

At the general mean of these times, and for the position of Greenwich, we have, very nearly, for the change in the time of the phase produced by a change of 1″ in the longitude, λ, and the latitude, β, of the moon,

$$\text{Beginning of totality; } \delta t_1 = -2.13\,\delta\lambda + 1.52\,\delta\beta$$
$$\text{End of totality; } \delta t_2 = -2.04\,\delta\lambda - 2.04\,\delta\beta.$$

To make use of these quantities, we must express the correction of the moon's true longitude and latitude in terms of that of her mean longitude and longitude of the node. We find, from the formulæ already given,

$$\delta\lambda = 1.14\,\delta\varepsilon$$
$$\delta\beta = -0.100\,\delta\varepsilon + 0.088\,\delta\theta,$$

which expressions are to be substituted in the preceding equations of condition.

We have now to combine the observations. Their remarkable discordance renders the final result greatly dependent on the relative weights assigned, and these are necessarily a matter of judgment. The most widely discordant ones are those which we should suppose, from the data before us, to have been the best, namely, Halley's and Flamsteed's. Altogether, I think, the most probable result will be obtained by giving Halley and Pound the weight 1, and Flamsteed weight 2. At the same time, I confess, that my judgment may be influenced in this decision by the entirely improbable correction to the tabular times which is indicated by Flamsteed's observations, and that but for this I might assign a greater relative weight to the latter. On the other hand, were it not for the equally great deviation of Halley's observations from probability in the opposite direction, I might assign him a greater weight than Pound, and the result would then be but little altered. I shall, therefore, adhere to the above weights. This combination will give,

Mean correction to beginning . . . . $\delta t_1 = -44^s$

Mean correction to end . . . . $\delta t_2 = -31^s$.

By substituting the values of δt, $\delta\lambda$, etc., in the equations of condition, they become,

$$2.58\,\delta\varepsilon - 2.0\,\delta L - 0.134\,\delta\theta = 44$$
$$1.76\,\delta\varepsilon - 2.0\,\delta L + 0.179\,\delta\vartheta = 31.$$

Putting δL, the correction to the sun's longitude, equal to zero, we derive from these equations

$$\delta \varepsilon = + 16''.2 \pm 2''.5$$
$$\delta \theta = - 20''.$$

The correction to θ will be obtained so much more accurately from other observations that we need not consider it here.

§ 15.

DISCUSSION OF DEVIATIONS IN THE MOON'S MEAN MOTION AS INDICATED BY THE PRECEDING OBSERVATIONS.

We now employ the preceding results for the study of the principal problem in view as the object of these researches. If we suppose no deviation in the mean motion of the moon except that which is due to the gravitation of other bodies of our system, this mean motion would be constant with the exception of a secular acceleration, the amount of which has been accurately fixed by theory. It is, however, well known that the secular acceleration given by observation is not the same as that deduced from theory, and astronomers have generally been agreed that the apparent difference may be due to a retardation of the earth's axial rotation. Thus, the apparent secular acceleration will be made up of two parts,—the one a real acceleration; the other an apparent one, due to the change in our measure of time.

But when we study the problem more closely, we shall find that the hypothesis of a constant tidal retardation fails to account for the observed mean motion of the moon, and that we must either suppose this retardation variable, sometimes even becoming an acceleration, or we must suppose the mean motion of the moon subject to changes which have not yet been accounted for. Let as now inquire what deviations of the moon's mean motion remain unaccounted for. For this purpose, we collect from the two preceding sections the following system of residual corrections, obtained from the observations of eclipses and occultations made since the invention of the telescope. We begin with individual results from each eclipse and from groups of occultations. It may once more be remarked that the probable errors here assigned are, for the most part, mere estimates, founded on a consideration of all the attendant circumstances. Some such estimate is absolutely necessary for the subsequent combination of the observations; and, as there are no data for the rigorous computation of probable errors, we are necessarily left in part to the exercise of our judgment.

Individual Corrections to the Mean Longitude of the Moon in HANSEN'S *Tables, with the Sources whence derived.*

1621.4, $\delta\varepsilon =$	$+ 78''$	$\pm 14''$	GASSENDUS, beginning and end of eclipse.
1630.4	$+ 35$	± 25	GASSENDUS, beginning of eclipse.
1633.3	$+ 53$	± 13	GASSENDUS, eclipse ⊙, phases.
1635.7	$+ 57$	± 9	BULLIALDUS and GASSENDUS, 13 occultations.
1639.4	$+ 34$	± 11	Eclipse ⊙, by GASCOIGNE.
1639.4	$+ 23$	± 9	Eclipse ⊙, by GASSENDUS.
1639.4	$+ 27$	± 5	Eclipse ⊙, by HORROX.

1639.4, $\delta\varepsilon = -27'' \pm (?)''$		Eclipse ⊙, by HEVELIUS.
1645.2	$+34 \pm 10$	4 phases of occultations, by HEVELIUS.
1645.6	$+51 \pm 8$	Eclipse ⊙, by HEVELIUS.
1652.3	$+38 \pm 10$	Eclipse ⊙, by HEVELIUS.
1654.6	$+31 \pm 8$	Eclipse ⊙, by WALTERIUS.
1661.2	$+37 \pm 6$	Eclipse ⊙, by HEVELIUS.
1662.0	$+38 \pm 5$	Occultations, by HEVELIUS.
1666.5	$+25 \pm 10$	Eclipse ⊙, by HEVELIUS.
1673.9	$+39 \pm 4$	Occultations, by HEVELIUS.
1676.4	$+23 \pm 6$	Eclipse ⊙, by FLAMSTEED.
1680.0	$+31 \pm 5$	Occultations, by HEVELIUS.
1680.0	$+29.4 \pm 1.0$	Occultations by FLAMSTEED and the Paris astronomers.
1684.5	$+24 \pm 4$	Eclipse ⊙, by FLAMSTEED.
1684.5	$+32 \pm 2$	Eclipse ⊙, by LA HIRE.
1699.7	$+24.8 \pm 2.0$	Eclipse ⊙, by LA HIRE.
1706.4	$+24.1 \pm 2.0$	Eclipse ⊙, by LA HIRE.
1712.5	$+14.8 \pm 0.6$	Occultations, by the Paris astronomers.
1715.3	$+16.2 \pm 2.5$	Eclipse ⊙, by FLAMSTEED, HALLEY, and POUND.
1715.3	$+8 \pm 4$	Eclipse ⊙, by CASSINI, at Marly.
1715.3	$+10.3 \pm 1.5$	Eclipse ⊙, by the LA HIRES, at Paris.
1728.5	$+7.3 \pm 1.5$	Occultations, by DELISLE, etc.

The discordances among the older results are, on the whole, not greater than what we should expect from the probable errors assigned, except in the case of the eclipse of 1639. In fact, if we suppose the error of the tables to diminish uniformly from 60″, in 1620, to 30″, in 1680, the deviation of the result will in no case exceed 1.5 × the probable error assigned, except in the case of the observations of the eclipse of 1639, by GASSENDUS and HORROX, where the deviations are, respectively, 3.0 and 4.6 × probable error. The question whether the observations are or are not to be taxed with this apparent error cannot now be settled.

To investigate the questions now under consideration, we must have the correction to HANSEN's Tables given by observations from 1750 to the present time. From the comparisons published by HANSEN himself in the *Monthly Notices of the Royal Astronomical Society*, it would appear that the correction from 1750 to 1850, inclusive, is very nearly zero. The course of the moon since 1850 has been investigated in Part III of the *Papers published by the Commission on the Transit of Venus*, from which it appears that, at the epoch 1875.0, the meridian observations at Greenwich and Washington indicate a correction to the moon's mean longitude of $-9''.7$. But the occultations about the same time give a correction nearly two seconds less, so that we may consider the correction at this epoch to be $-8''$.

The first question to be considered is how nearly the observations can be represented by theory without any empirical correction. It is well known that HANSEN introduced into his tables a term depending on the argument 8 times the mean motion of Venus minus 13 times the mean motion of the earth, which is to be regarded as empirical, since it has never been satisfactorily shown to have any theoretical existence. We

must therefore remove this term from the theory to be compared with observation. The secular acceleration is, however, to be left arbitrary, because it depends in part on the unknown tidal retardation of the earth's rotation.

For convenience in solving the equations, we shall graphically interpolate the individual corrections to the moon's mean longitude just collected, so as to give the value of that correction for intervals of a quarter of a century. The values of the corrections to HANSEN'S Tables thus interpolated, of HANSEN'S doubtful term, and of the resulting correction to a pure theory, are as follows; V_2 representing the doubtful term and $\delta\varepsilon'$ the correction to pure theory:—

1625,	$\delta\varepsilon = +50'' \pm 13''$;	$V_2 = -17''.1$;	$\delta\varepsilon' = +33''$
1650	$+39 \pm 5$	-21.4	$+18$
1675	$+32 \pm 1$	-16.8	$+15$
1700	$+21 \pm 1$	-5.2	$+16$
1725	$+7 \pm 1$	$+8.6$	$+16$
1750	0 ± 1	$+18.9$	$+19$
1775	0 ± 1	$+21.2$	$+21$
1800	0 ± 1	$+14.7$	$+15$
1825	0 ± 1	$+2.1$	$+2$
1850	0 ± 1	-11.4	-11
1875	-8 ± 1	-20.1	-28

It is clear, without computation, that these residuals cannot be represented by corrections to the epoch, mean motion, and secular acceleration. The only secular acceleration we can obtain is an approximation to a mean value, which may have different values according to the mode of using the data, because the mean in question does not admit of precise definition. The deviation during recent years is such that the secular acceleration will come out smaller the greater the weight we assign to the modern observations. To obtain the best result from the ancient and modern observations combined, it seems advisable to assign a minimum probable error of 4″ or 5″ to each residual of the modern observations.

The equations of condition given by the ancient and modern corrections are as follow. In these equations we have put $\delta\varepsilon$ for the correction to the moon's mean longitude in seconds in 1700, and δn for the correction of the centennial mean motion at the same epoch, while δs is the correction to HANSEN'S secular acceleration. The first four equations are those given by PTOLEMY'S lunar eclipses, p. 44, while the next three are those from the Arabian observations, p. 54. To obtain a more convenient treatment of the equations, the residuals of the ancient observations are expressed in minutes of arc instead of seconds. The equations expressed in seconds may be considered as divided by 60 throughout, and the weights as multiplied by 3600. The unit of weight is supposed to correspond to a probable error of about 6 units

Equations of Condition for the Moon's Mean Motion, etc.

Date					Wt.	r
-687;	$0.017\,\delta\varepsilon$	$-0.40\,\delta n$	$+9.55\,\delta s$	$=-11$;	Wt. $=3$;	$r=+16'$
-381;	.017	-0.35	$+7.28$	-27	2	-7
-189;	.017	-0.31	$+5.95$	-20	4	-4
$+134$;	.017	-0.26	$+4.11$	-16	3	-6
850;	.017	-0.14	$+1.20$	-4.4	8	-2.4
927;	.017	-0.13	$+0.99$	-1.1	16	$+0.3$
986;	0.017	-0.12	$+0.84$	-4.8	30	-3.8
1625;	1.00	-0.75	$+0.56$	$+33$	1	$+6''.1$
1650;	1.00	-0.50	$+0.25$	18	1	-6.9
1675;	1.00	-0.25	$+0.06$	15	2	-7.4
1700;	1.00	0.00	0.00	16	2	-3.6
1725;	1.00	$+0.25$	$+0.06$	16	2	-0.3
1750;	1.00	0.50	$+0.25$	19	2	$+6.4$
1775;	1.00	0.75	$+0.56$	21	2	$+12.5$
1800;	1.00	1.00	$+1.00$	15	2	$+11.1$
1825;	1.00	1.25	$+1.56$	$+2$	2	$+3.0$
1850;	1.00	1.50	$+2.25$	-11	2	-4.6
1875;	1.00	1.75	$+3.06$	-28	2	-15.8

It will be noticed that the corrections from the Arabian observations employed in the equations are a little different from those given on p. 54. This arises from the fact that equal weight was given to all the eclipses in forming these equations. The final result is substantially the same on either system.

Treating the above equations by the method of least squares, we have the normals:—

$$\begin{array}{rrrl} 20.02\,\delta\varepsilon & +12.07\,\delta n & +20.62\,\delta s & =+174.0 \\ 12.07 & +20.60 & -9.66 & =+15.2 \\ 20.62 & -9.66 & +657.1 & =-1687.0 \end{array}$$

The solution of which gives:—

$$\left.\begin{array}{l} \delta\varepsilon=+19''.57 \\ \delta n=-12''.31 \\ \delta s=-3''.36 \end{array}\right\}\text{Epoch, 1700.}$$

If we transfer the epoch to 1800, the corrections will be:—

$$\left.\begin{array}{l} \delta\varepsilon=+3''.90 \\ \delta n=-19''.03 \\ \delta s=-3''.36 \end{array}\right\}\text{Epoch, 1800.}$$

If we substitute these values of the unknown quantities in the equations of condition, we shall have the residuals following the equations. We see that in the case of the modern observations the residuals are of an entirely inadmissible magnitude;

it is therefore certain that the existing theory will not represent observations with any value whatever of the secular acceleration. Still, the correction which we have deduced for the secular acceleration is clearly indicated by the combination of all the observations. HANSEN's adopted value being $12''.17$, we are led to the value

$$s = 8''.8$$

as that which, on the whole, best satisfies the observations which we have discussed.

Respecting the cause of the outstanding deviations, we may make two hypotheses:—

(1) That these deviations are only apparent ones, arising from inequalities in the axial rotation of the earth. The deviation of the observed secular acceleration from the theoretical value $6''.18$ has long been attributed to a retardation of the earth's rotation, and by supposing this retardation to be itself a variable quantity, and indeed sometimes to change into an acceleration, we may completely account for the observed deviations.

(2) We may suppose the deviations to arise from one or more inequalities of long period in the actual mean motion of the moon.

Let us consider these two hypotheses in order. We have first to see what results follow, if we suppose the theory of gravitation to correctly account for all real changes in the mean motion of the moon, and attribute the observed deviations to changes in the earth's axial rotation, or the length of the mean day. To find what these deviations really are, we must take out the effect of HANSEN's increase of the secular acceleration as well as the empirical term due to the action of Venus from the theory to be compared. The latter has been taken out wherever necessary in the preceding exhibit of the corrections to the moon's mean longitude, and it now remains to consider the former.

The sidereal acceleration adopted in HANSEN's tables is	$12''.18\ T^2$
While DELAUNAY has found from theory	$6''.18\ T^2$
So that the excess of HANSEN's tables is	$+\ 6''.00\ T^2$.

If we apply this correction to the tabular residuals, we shall have the results of the hypothetical deviations from a certain uniform measure of time. This measure being arbitrary, we shall take it so that the observed and the assumed measures shall agree in 1750 and 1850. This will be effected by correcting the residuals by the quantity

$$-\ 29''.5 + 18''.0\, T + 6''.0\ T^2,$$

T being counted in centuries from 1700. Applying this correction to the fundamental residuals, we have the series of outstanding corrections to pure theory given in the second column of the following table, while, in the third column, these residuals are converted into seconds of time. The significance of the numbers in question is this:—

If we suppose the accepted theory of the moon's motion to be perfect, and the observed deviations from theory to be due to inequalities in the earth's axial rotation, then the last

column of this table shows the amount in time by which the earth is in advance of an assumed uniformly revolving earth. These numbers must therefore be subtracted from the times indicated by astronomical observations in order to reduce them to a uniform measure of time.

Epoch	$\delta\varepsilon$	Δt
-687	$+38'.6$	-70^m
-381	$+9.9$	-18
-189	$+9.6$	-17
$+134$	$+3.5$	-6
846	-0.2	0
926	$+2.1$	-4
986	-1.3	$+2$
1625	$-6''.6$	$+12^s$
1650	-19.0	$+35$
1675	-18.6	$+34$
1700	-13.5	$+25$
1725	-8.6	$+16$
1750	0.0	0
1775	$+8.4$	-15
1800	9.5	-17
1825	$+4.4$	-8
1850	0.0	0
1875	-7.6	$+14$

These corrections are so minute that their independent detection by existing observations is barely possible. The most promising means of detection is afforded by the eclipses of the first satellite of Jupiter, which have been observed since 1670. Next in order come meridian observations of Venus during several months on each side of her superior conjunction, the discussion of which would be extremely laborious, and would involve a complete re-examination of the theory of the motion of Venus. Transits of Mercury also afford some hope, but, unfortunately, HALLEY's excellent observation of the transit of 1678 is vitiated by some defect in his clock-error, which cannot be investigated for want of data.

If the hypothesis in question is correct, the problem of predicting the moon's motion with accuracy through long intervals of time must be regarded as hopeless, since it cannot be expected that variations in the earth's axial rotation will conform to any determinable law. Success in tracing the deviations in question to the moon itself and to the theory of gravitation is therefore a consummation to be hoped for.

Passing now to the second hypothesis, a glance at the residuals of the equations of condition on page 263 shows that the modern observations may be very nearly represented by a term having a period of between 250 and 300 years. Let us then inquire how good this representation can be made if we suppose an empirical correction to HANSEN's first term depending on the action of Venus, the period of which is 273 years. In this inquiry, we confine ourselves to the modern observations; and we must introduce, in addition to the term sought, new corrections to the moon's epoch and mean motion. Let us put

$$A = 18\,V - 16\,E - g;$$

V being the mean longitude of Venus, E that of the earth, and g the mean anomaly of the moon. The residual corrections will then be of the form

$$\delta\varepsilon + T\delta n + x \sin A + y \cos A.$$

Counting T in centuries from 1800, the equations of condition will be:—

$$\begin{array}{lllll} \delta\varepsilon - 1.75\,\delta n & - 0.73x & + 0.68y & = + \;\; 6''.1 & \text{Wt.} = \tfrac{1}{2} \\ \delta\varepsilon - 1.50 & - 0.24 & + 0.96 & = - \;\; 6''.9 & 1 \\ \delta\varepsilon - 1.25 & + 0.33 & + 0.95 & = - \;\; 7''.4 & 5 \\ \delta\varepsilon - 1.00 & + 0.79 & + 0.62 & = - \;\; 3''.6 & 5 \\ \delta\varepsilon - 0.75 & + 1.00 & - 0.09 & = - \;\; 0''.3 & 3 \\ \delta\varepsilon - 0.50 & + 0.88 & - 0.47 & = + \;\; 6''.4 & 4 \\ \delta\varepsilon - 0.25 & + 0.48 & - 0.87 & = + 12''.5 & 4 \\ \delta\varepsilon \quad 0.00 & - 0.07 & - 1.00 & = + 11''.1 & 4 \\ \delta\varepsilon + 0.25 & - 0.60 & - 0.80 & = + \;\; 3''.0 & 4 \\ \delta\varepsilon + 0.50 & - 0.94 & - 0.34 & = - \;\; 4''.6 & 8 \\ \delta\varepsilon + 0.75 & - 0.97 & + 0.22 & = - 15''.8 & 10 \end{array}$$

The unit of weight is supposed to correspond to a probable error of about $\pm 2''$.

The treatment by least squares leads to the normals:—

$$\begin{array}{lllll} 48.500\,\delta\varepsilon & - \;\; 6.375\,\delta n & - \;\; 6.465\,x & - \;\; 3.660\,y & = - 122''.55 \\ - 6.375 & + 27.401 & - 21.138 & - \;\; 9.975 & = - \;\; 89''.26 \\ - 6.465 & - 21.138 & + 28.946 & + \;\; 3.107 & = + 196''.17 \\ - 3.660 & - \;\; 9.975 & + \;\; 3.107 & + 19.492 & = - 182''.72. \end{array}$$

The solution of these equations gives:—

$$\left.\begin{array}{l} \delta\varepsilon = - \;\; 5''.04 \\ \delta n = - 10''.14 \end{array}\right\} \text{epoch, 1800.}$$

$$\begin{array}{l} x = - \;\; 0''.09 \\ y = - 15''.49. \end{array}$$

The outstanding residuals are:—

1625	$+ 3''.9$	1775	$+ 1''.6$
50	$- 2''.2$	1800	$+ 0''.6$
75	$- 0''.3$	25	$- 1''.9$
1700	$+ 1''.0$	50	$+ 0''.2$
25	$- 0''.8$	1875	$+ 0''.2.$
50	$- 0''.8$		

The empirical alteration in question, therefore, represents the observations quite satisfactorily.

The additional diminution of $10''$ per century in the mean motion of the moon at the present time will necessitate a farther diminution of $0''.5$ in the value of the secular acceleration in order that the ancient observations may still be well represented. This will leave the moon's longitude unaltered by the last correction at the epoch -250.

To represent the Arabian observations without any mean residual, the diminution should be about $3''$, so that the observed secular acceleration would be reduced fully to its theoretical value, leaving no tidal retardation whatever. The best mean representation of the ancient observations is, however, given with the acceleration

$$8''.3.$$

The total correction to the mean longitude of HANSEN'S Tables now becomes

$$-1''.14 - 29''.17\,T - 3''.86\,T^2 - V_2 - 0''.09 \sin A - 15''.49 \cos A;$$

V_2 representing, as before, the empirical term due to the action of Venus; A, the angle $18\,V - 16\,E - g$; and T, the time counted in centuries from 1800.

To give a clear view of the course of these corrections, they have been tabulated for ten-year intervals from 1620 to 1900. The results are shown in the following table:—

Year.	A	$-V_2$	$-15''.5 \times \cos A$	Secular Terms.	Total Corr.
	°	"	"	"	"
1620	306.5	+ 15.3	− 9.2	+ 39.0	+ 45.1
30	319.6	+ 18.7	− 11.8	+ 37.4	+ 44.3
40	332.8	+ 20.8	− 13.8	+ 35.7	+ 42.7
50	346.0	+ 21.5	− 15.0	+ 33.9	+ 40.4
60	359.2	+ 20.7	− 15.5	+ 32.1	+ 37.3
70	12.4	+ 18.5	− 15.1	+ 30.2	+ 33.6
80	25.6	+ 15.0	− 14.0	+ 28.2	+ 29.2
90	38.8	+ 10.4	− 12.1	+ 26.2	+ 24.5
1700	52.0	+ 5.2	− 9.5	+ 24.1	+ 19.8
10	65.1	− 0.4	− 6.5	+ 21.9	+ 15.0
20	78.3	− 5.9	− 3.1	+ 19.7	+ 10.7
30	91.5	− 11.1	+ 0.4	+ 17.4	+ 6.7
40	104.7	− 15.5	+ 3.9	+ 15.0	+ 3.4
50	117.9	− 18.9	+ 7.3	+ 12.5	+ 0.9
60	131.0	− 20.8	+ 10.2	+ 10.0	− 0.6
70	144.3	− 21.4	+ 12.6	+ 7.3	− 1.5
80	157.5	− 20.6	+ 14.3	+ 4.6	− 1.7
90	170.7	− 18.3	+ 15.3	+ 1.8	− 1.2
1800	183.9	− 14.7	+ 15.5	− 1.1	− 0.3
10	197.0	− 10.2	+ 14.8	− 4.1	+ 0.5
20	210.2	− 4.9	+ 13.4	− 7.1	+ 1.4
30	223.4	+ 0.7	+ 11.3	− 10.3	+ 1.7
40	236.6	+ 6.2	+ 8.5	− 13.5	+ 1.2
50	249.8	+ 11.4	+ 5.4	− 16.7	+ 0.1
60	263.0	+ 15.7	+ 1.9	− 20.0	− 2.4
70	276.2	+ 19.0	− 1.7	− 23.4	− 6.1
80	289.4	+ 20.9	− 5.2	− 26.9	− 11.2
90	302.6	+ 21.5	− 8.4	− 30.4	− 17.3
1900	315.8	+ 20.6	− 11.1	− 34.1	− 24.6

It will be instructive to notice how these resulting corrections compare with those which have been already deduced from individual observations or groups of observations. This is shown in the following table. The observed corrections and the probable errors $\pm \varepsilon$ are taken without change from the table given on pages 261 and 262.

Date.	Observed Correction.	Formula.	Difference.	$\pm \varepsilon$	Wt.
	″	″	″	″	
1621.4	+ 78	+ 45	+ 33	14	3
1630.4	35	44	− 9	25	1
1633.3	53	44	+ 9	13	3
1635.7	57	43	+ 14	9	6
1639.4	34	43	− 9	11	5
"	23	43	− 20	9	6
"	27	43	− 16	5	6
1645.2	34	41	− 7	10	2
1645.6	51	41	+ 10	8	3
1652.3	38	40	− 2	10	2
1654.6	31	39	− 8	8	3
1661.2	37	37	0	6	3
1662.0	38	37	+ 1	5	4
1666.5	25	35	− 10	10	1
1673.9	39	32	+ 7	4	6
1676.4	23	31	− 8	6	3
1680.0	31	29	+ 2	5	4
"	29.4	29.0	+ 0.4	1.0	100
1684.5	24	27	− 3	4	6
"	32	27	+ 5	2.0	25
1699.7	24.8	19.8	+ 5.0	2.0	25
1706.4	24.1	16.6	+ 7.5	2.0	25
1712.5	14.8	13.9	+ 0.9	0.6	45
1715.3	16.2	12.6	+ 3.6	2.5	3
"	8.0	12.6	− 4.6	4.0	1
"	10.3	12.6	− 2.3	1.5	7
1728.5	7.3	7.5	− 0.2	1.5	7

By comparing the corrections with the probable errors it will be seen that

The residuals are less than the probable error in 11 cases;
The residuals are equal to the probable error in 2 cases;
The residuals are greater than the probable error in 14 cases.

If the theory were itself perfect, this would indicate that the probable errors assigned are, in the mean, somewhat too small. In the case of the eclipse of 1639, by HORROX, it may be regarded as certain that the assigned probable error is too small, as, through inadvertence, proper account was not taken of the uncertainty of his clock-correction.

The results are divided into groups, and the mean by weights has been taken. It will be remarked that each group has its own unit of weight. The mean results for the corrections still outstanding will then be as follows:—

1635.9,	$\delta\varepsilon = -2''.0 \pm 4''.2$
1649.5	$-1''.2 \pm 4''.2$
1662.3	$-0''.8 \pm 3''.5$
1681.7	$+1''.3 \pm 0''.8$
1699.7	$+5''.0 \pm 2''.0$
1706.4	$+7''.5 \pm 2''.0$
1713.1	$+0''.5 \pm 0''.5$
1728.5	$-0''.2 \pm 1''.5$.

It will be seen that the results are, on the whole, as good as could be expected except in the case of the solar eclipses of 1699 and 1706, where the observations of La Hire indicate a correction of several times the probable error. Whether this arises from some systematic error in the observations, or from a real deviation of the moon at those times, must be left to future investigation.

§ 16.

OBSERVED LIMITS OF THE MOON'S SHADOW DURING ITS PASSAGE OVER ENGLAND IN THE TOTAL ECLIPSE OF 1715, WITH A DETERMINATION OF THE CORRECTION TO THE MOTION OF THE MOON'S NODE.

The most remarkable and valuable of the observations of this eclipse were those organized by Halley for the purpose of determining the limits of the shadow-path. As the duration of totality increases very rapidly when we first enter the limits of this path, this limit can be fixed with great precision by an observation of duration made a short distance within. Such an observation is of especial value for determining the position of the moon's node. The mode of treating observations of this class is as follows:—

Putting τ_0 for the central duration corresponding to the position of the observer, τ for the observed duration, and ρ_1 for the radius of the shadow, if we compute k from the formula

$$\sin k = \frac{\tau}{\tau_0},$$

the shortest distance of the observer from the centre of the shadow will be

$$\Delta = \rho_1 \cos k.$$

The value of τ_0 is given by the formula

$$\tau_0 = \frac{\rho_1}{\sqrt{X'^2 + Y'^2}}.$$

If only one limit is observed, this result will be subject to errors of the semi-diameters of the sun and moon; but these errors will be eliminated from the mean observations made near the two limits.

The observations we are now to use are found in HALLEY's paper in the *Philosophical Transactions* for 1715. The fixing of the exact geographical positions of the places of observation at first presented a difficulty, which was entirely removed through the kindness of General Sir HENRY JAMES, Chief of the Ordnance Survey of England, who sent me a complete and accurate list of the positions in question.

The following is a summary of all the observations, as given by HALLEY:—

A.—*Stations near Southern Limit.*

1. Norton Court, about 10 miles this side Canterbury. Observer, Rev. Dr. JOHN HARRIS, S. T. D., R. S. S., Prebendary of Rochester. Duration, one minute, or rather less.

2. Bocton, about midway between Norton Court and Canterbury. Observers, the inhabitants. Eclipse, hardly total, a small star being left on the lower part of the sun at greatest obscuration.

3. Cranbrook, in Kent. Observer, WILLIAM TEMPLE, Esq., R. S. S. Sun extinguished for a moment and then reappeared.

4. Wadhurst, beyond Turnbridge Wells. Total, but no duration given.

5. Lewis. Eclipse total for "some short time".

6. Brightling. Not quite total.

The following quantities may be assumed as having the same value for all these stations:—

Value of ζ or distance from place of reference		0.658
Augmentation of radius of shadow		.00305
Radius of shadow on plane of reference		.01284
Radius of shadow at points of observation		.01589
Relative velocity, or $\sqrt{X'^2 + Y'^2}$	(Log.)	9.6720
Duration on central line		$243^s.4$.

We now take the stations in the order in which they are given.

1. *Norton Court.*—In all probability, the duration was between 52^s and one minute.*

$$\text{If } \tau = 52^s, \text{ then } \sin k = 0.214; \ \Delta = .01552.$$
$$\text{If } \tau = 60^s, \text{ then } \sin k = 0.247; \ \Delta = .01540.$$

The mean of these two results is .01546, with a probable error of less than 6 in the last place.

2. *Bocton.*—The sun could not have presented this appearance at any appreciable distance outside the shadow. Probably the point was exactly on the limit, the sun's limb shining through a depression in the moon's limb. Possibly, the appearance described may have been due to a protuberance; but this does not seem likely. We may therefore put $\Delta = .01589$.

3. *Cranbrook.*—Here also observed $\Delta = \rho_1 = .01589$.

4 and 5.—These stations give only $\Delta < .01589$, but, in the case of Lewis, probably not much less, since a duration of 30^s would correspond to $\Delta = .01577$.

6. *Brightling.*—This only gives $\Delta > .01589$.

*At the time of writing this I did not notice that HALLEY elsewhere gave data showing the duration to be exactly 59^s.

The comparison of these results with the tables is as follows; the positions are those furnished by Sir HENRY JAMES. The tabular values of Δ, the minimum distance of the point of observation from the axis of the shadow, are computed by the formulæ of § 7:—

	Latitude.	Longitude.	Tabular Δ.	Observed Δ.	Correction.
	° ′	′			
Norton Court .	51 19.0	− 49.4	+ .01597	.01546	− .00051
Bocton . . .	51 17.7	− 57.4	.01679	.01589	− .00090
Cranbrook .	51 5.7	− 32.4	.01682	.01589	− .00093
Wadhurst . .	51 3.8	− 20.5	.01624	.01589 minus.	− .00035 and more.
Lewis . . .	50 52.6	− 0.8	.01656	{ .01589 minus. { .01577.	− .00067 and more. − .00079:
Brightling .	50 57.7	− 22.9	.01740	.01589 plus.	− .00167 and less.

The mean of the first three results, giving double weight to Norton Court, is .00071 $\pm$.00010. But since the Lewis observation gives a minimum limit of .00067, the most probable value of the correction may be estimated at — .00075 $\pm$.00008.

B.—*Stations near Northern Limit.*

1. Haverford-West. Observer, Rev. ROGER PROSSER. Eclipse total a minute and a half.

2. Shrewsbury in Shropshire. Observer, Dr. HOLLINGS. Duration of totality, $1^{m}\ 40^{s}$.

3. Darrington, about 2 miles this side Pontefract. Observer, THEOPHILUS SHELTON, Esq. The sun reduced almost to a point resembling the planet Mars, and then the light began to increase.

4. Barnsdale, 3 miles south of Darrington. The eclipse "just total".

5. Badsworth. Authority, the Rev. and Learned Mr. DAUBUZ. The corona seen, and therefore the eclipse total.

6. Witley, the seat of Lord FOLEY. Duration, $3^{m}\ 15^{s}$.

We have from the elements:—

		Hav. W.	Other st.
Mean value of ϱ		0.608	0.632
Augmentation of radius of shadow		.00281	.00291
Radius of shadow on plane		.01284	.01284
Radius of shadow at station		.01565	.01575
Relative velocity	(Log.)	9.6862	9.6805
Duration on central line		$232^{s}.0$	$236^{s}.6$

The following values of Δ are derived from the observations:—

1. *Haverford.*—sin $k = .388$; $\Delta = .01443$.

2. *Shrewsbury.*—sin $k = .423$; $\Delta = .01427$.

3. *Darrington.*—Here the phenomenon corresponds almost exactly to that at Bocton in the south; we therefore put $\Delta =$ radius of shadow $= .01575$.

4. *Barnsdale.*—Same value of Δ.

5. *Badsworth.*—$\Delta <$ 01575, but probably very little less.

6. *Witley.*—So far from the limit as to be entirely unreliable; the results, however, are, sin $k = .825$; $\Delta = .00891$.

Exhibiting the tabular results in the same form as for the southern limits, they will be shown as follows:—

	Latitude.	Longitude.	Tab. Δ.	Obs. Δ.	Corr. to Δ.
	° ′	° ′			
Haverford W.	51 48.1	+ 4 58.3	− .01418	− .01443	− .00025
Shrewsbury .	52 42.5	+ 2 44.5	− .01266	− .01427	− .00161
Darrington .	53 40.5	+ 1 16.0	− .01511	− .01575	− .00064
Barnsdale . .	53 37.1	+ 1 13.7	− .01441	− .01575	− .00134
Badworth . .	53 37.8	+ 1 18.0	− .01484	− .01564 :	− .00080 :
Witley . . .	52 16.9	+ 2 20.2	− .00701	− .00891 :	− .00190 :

The mean correction derived from the first four stations is —.00096. But the observation of the corona at Badworth would indicate a correction numerically less than .00091, which, however, we cannot regard as certain. Altogether, I think we may regard —.00090 as the most probable correction.

We thus have, for the correction to the tabular position of the shadow-path:—

From observations of southern limit, —.00075
From observations of northern limit, —.00090
Mean correction, —.00082.

The correction expressed in terms of the geocentric co-ordinates of the moon, relative to the sun, and of the moon's parallax, is, in units of the 5th place of decimals,

$$-0.44\,\delta\lambda + 27.3\,\delta\beta + 13\,\delta\Pi.$$

The same quantity, being expressed in terms of the correction to the moon's mean longitude, ε, the sun's true longitude, L, and the correction to the longitude of the moon's node, is,

$$\delta\Delta = -3.26\,\delta\varepsilon + 0.4\,\delta L + 2.40\,\delta\theta + 13\,\delta\Pi = -82,$$

the units of the corrections being seconds of arc. The value of $\delta\varepsilon$ given by all the observations of the eclipse is $+11''.2$, while the formula gives $+12''.6$. The most probable value is perhaps the mean of these two results, or $+11''.9$. We necessarily suppose δL and $\delta\Pi$ equal to zero, so that the value of $\delta\theta$ for this epoch will be,

$$\delta\theta = -18'' \pm 5''.$$

From the occultations, we have found (p. 235), $i\,\delta\theta = -0''.14 \pm 1''.2$, which would give

$$\delta\theta = -1'' \pm 13''.$$

The most probable mean result for 1710 is

$$\delta\vartheta = -16''.$$

In *Investigation of Corrections to* Hansen's *Tables of the Moon*,* p. 36, is deduced for 1868

$$\delta\theta = +4''.5.$$

* Part III of *Papers published by the Commission on the Transit of Venus.*

The correction to HANSEN's motion of the moon's node in one century, therefore, comes out,

$$+13''.0 \pm 4''.$$

In this result, however, no weight is given to the observations used by HANSEN himself. Altogether, I think we may regard the most probable correction as about 10″. The motion of the node being negative, this correction diminishes both its absolute value and the argument of latitude by the quantity

$$10'' \, T,$$

T being counted in centuries from 1850. This result, though nearly certain with respect to its algebraic sign, cannot be regarded as definitive, as it will be affected by any correction to HANSEN's value of the moon's parallax.

§ 17.

CONCLUDING REMARKS ON THE VALUE OF THE SECULAR ACCELERATION DEDUCED IN THIS PAPER.

The author is conscious that there may be room for differences of opinion respecting the reality of the very large diminution of the secular acceleration which is indicated by the preceding discussion. A clear summary of the evidence on both sides of the question, and a statement of the data by which it may be settled, may form a fitting conclusion to this investigation. In the first place, it is to be remarked that there are three pieces of evidence, all of which militate against the diminution here deduced, and in favor of the large value found by HANSEN. They are as follows:—

1. The supposed ancient total eclipses known respectively as the eclipse of THALES and the eclipse at Larissa. If the total eclipse of −584, May 28, really passed over the region in which the celebrated battle described by HERODOTUS is supposed to have been fought, and if the eclipse of −556, May 19, was really total at the supposed site of Larissa, then no appreciable change of HANSEN's longitude of the moon during those times is admissible. The reasons for doubting the reality of these eclipses are set forth so fully in § 3 that they need not be repeated here.

2. The lunar eclipse of −382, reported as observed at Babylon. It is certain that if this eclipse was really seen at Babylon, no appreciable diminution of HANSEN's longitude at this time can be admitted.

3. Those lunar eclipses cited by PTOLEMY without a statement of the phase observed, it being hitherto assumed that the times noted are those of the middle of the eclipse. These eclipses are in every way so uncertain that no great stress can be laid upon them.

The sources of evidence which indicate the diminution here deduced are these two:—

α. The Ptolemaic eclipses of the *Almagest*, discussed in § 4 of this paper.

β. The Arabian eclipses, discussed in § 5.

It must be remarked that this is not a case in which the discordant data can be combined by weights. The evidence included under heads 1 and 2 is either conclusive, or false, and therefore worthless. Either the solar eclipses were total at the points

supposed, or they were not. If they were, we cannot change HANSEN'S longitude; if they were not, we can deduce nothing from them.* The same remark applies to the lunar eclipse of -382, according to whether we suppose it to have been really seen at Babylon or not. Data α and β do not admit of being disposed of so precisely, but we cannot suppose the acceleration much greater than $8''.3$ without supposing systematic errors which seem quite improbable. To me these errors seem more improbable than mistakes in data 1 and 2, and therefore I regard the small value of the secular acceleration as having the preponderance of evidence in its favor.

The Arabian observations are far more reliable than those of PTOLEMY; it is therefore of interest to know what value of the secular acceleration would be obtained by combining them with the modern observations. The uncertainty respecting the inequalities of long period prevents us from deducing a precise result in this way, but we may safely say that it will differ very little from $7''$, and will therefore be scarcely larger than the theoretical value of the acceleration.

Let us now view the question from the opposite standpoint. Granting the reality of the problematical total eclipses, and therefore the correctness of HANSEN'S longitude five or six centuries before CHRIST, how will the undoubted eclipses of PTOLEMY and the Arabians be represented? In considering this question, we must remember that this representation will not be the same as by HANSEN'S unaltered tables, because the modern observations have shown that the latter need a correction to the mean motion of the moon at the present time, and the secular acceleration must be taken to accord with this change. It will be remembered that HANSEN'S value of the secular acceleration has in itself no foundation whatever either in observation or correct theory, and may therefore be changed at pleasure to fit the foundation which was found for it after its deduction, namely, the ancient eclipses. Since if we retain it unaltered, and admit the mean motion of the moon deduced from modern observations, the ancient eclipses will no longer be represented, we must, to place its value on any foundation at all, change it so that these eclipses shall be represented. The correction to the centennial mean motion given by modern observations we have already found to be $-29''.2$. If, then, we represent by δs the correction to HANSEN'S secular acceleration, the total correction to the moon's mean longitude T centuries after 1800 will be

$$-29''\,T + \delta s\, T^2.$$

To represent the ancient total eclipses as required, this quantity should be zero about five and a half centuries before CHRIST, or for $T = -23.5$. This condition will give

$$\delta s = -1''.25;\ s = 10''.9$$

for the secular acceleration which will represent at the same time the modern observa-

* In pronouncing the evidence to admit of no intermediate qualification between conclusiveness on the one hand, and falsity and worthlessness on the other, the author refers not so much to the historic narrative as to that interpretation of the narrative on which the hypothesis of a total eclipse is founded. Making allowance for the exaggerations and uncertainties to which narratives are liable when they pass through uncritical minds, he considers it not at all improbable that the narrative of HERODOTUS respecting the termination of a battle by darkness may have originated from a partial eclipse of the sun, which terrified or impressed the combatants, especially if this eclipse was almost total when the sun set. Hence, conceding that the phenomenon was really the eclipse of -584, he considers that the narrative does not enable us to decide whether the eclipse was total or partial.

tions and the total eclipses of THALES and Larissa. The correction to the moon's mean longitude T centuries after 1800 will then be

$$-T\,(29'' + 1''.25\ T).$$

We now desire to know how these corrections will alter the representation of the Ptolemaic and Arabian eclipses. For the former, the representation will be substantially the same as by the unaltered tables of HANSEN, because the factor $29'' + 1''.25\ T$ vanishes in the course of the observations. If the ancient solar eclipses are real, we must still suppose that the great mass of PTOLEMY'S eclipses are more than half an hour in error.

For the Arabian eclipses, T ranges from -9.7 to -8.0, and the consequent corrections to the tabular mean longitudes of the moon are:—

For 829, $\delta\varepsilon = +2'.7$
For 1000, $\delta\varepsilon = +2'.5$.

To find how the Arabian observations represent the revised theory, we must suppose that in the comparisons given on page 52 the tabular longitude is increased by these amounts before being compared with observation. We must therefore apply these values of $\delta\varepsilon$ negatively to the column $\varDelta l$ to obtain the new corrections. These new corrections are then converted into time by dividing them by the factor F, whereby we obtain the following corrections to the tabular times given by all the Arabian observations. In order to facilitate a discussion of the results, and the detection of any systematic error among the observations, a threefold classification is made according to whether the eclipse was of the sun or of the moon, whether the beginning or end was observed, and whether the altitude on which the time depends was observed east or west of the meridian. The latter distinction is important, because any constant error in determining the altitudes will have opposite effects on the two sides of the meridian.

BAGDAD.

Year	Ecl.		δt	Alt.
Year 829,	Ecl. ☉,	Beg.,	$\delta t = (+51^{m})$	Alt. E.
829	☉	End	$+24$	E.
854	☽	Beg.	$+12$	E.
856	☽	Beg.	$+9$	E.
923	☽	End	$+12$	E.
923	☉	End	$+23$	E.
925	☽	Beg.	$+1$	E.
925	☽	End	$+7$	E.
927	☽	Beg.	-8	E.
928	☉	End	$+16$	E.
929	☽	Beg.	(-53)	
933	☽	Beg.	$+7$	E.

CAIRO.

Year 977,	Ecl. ⊙, Beg., (S),	$\delta t = +16^m$	Alt. E.	
977	⊙ End	+ 10	E.	
978	⊙ Beg. (S)	+ 34	W.	
978	⊙ End	+ 9	W.	
979	☽ End	+ 16	?	
979	⊙ Beg. (S)	+ 15	W.	
979	☽ Beg.	+ 8	E.	
979	☽ End	+ 19	W.	
980	☽ End	+ 10	?	
981	☽ Beg.	+ 8	W.	
981	☽ End	+ 3	?	
981	☽ Beg.	+ 20	W.	
983	☽ End	+ 22	W.	
985	⊙ Beg.	+ 30	W.	
985	⊙ End	+ 19	W.	
986	☽ Beg. (S)	+ 27	W.	
990	☽ Beg.	− 20	E.	
993	⊙ Beg.	+ 6	E.	
993	⊙ End	+ 25	E.	
1002	☽ Beg.	+ 6	E. and $+10^m$ W.	
1004	⊙ Beg.	+ 16	W.	

Taking the means by classes, we find:—

From ⊙,	Beginning, mean	$\Delta t = +19^m$
⊙,	End,	$+18$
☽,	Beginning,	$+6$ or $+9^m$
☽,	End,	$+9$

The large difference between the solar and lunar eclipses arises in part from the fact that a change in the moon's longitude will generally cause a greater change in the time of a lunar than in that of a solar eclipse. The two means for ☽ beginning are derived, the one by retaining, and the other by rejecting, the discordant observation of 990.

In the Bagdad eclipses, the altitudes were all observed in the east, so that we should omit them entirely in comparing east and west observations. From the Cairo eclipses, we have:—

Mean result from east altitudes, $\Delta t = +7^m$ or $+12^m$,

according as the discordant observation of 990 is retained or rejected;

Mean result from west altitudes, $\Delta t = +20^m$.

That the positive correction of ten or fifteen minutes thus indicated should be unreal seems to me out of the question. If one had to explain their unreality, the most natural way of doing so would be to suppose that the observations were tampered